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ELECTRONIC DESIGN

NOVEMBER 22, 1993

FOR ENGINEERS AND ENGINEERING MANAGERS—WORLDWIDE

A SPECIAL ISSUE:

THE FUTURE OF COMPUTING

FUTURE DIRECTIONS IN:

- WORKSTATIONS
- STORAGE PERIPHERALS
- MICROPROCESSORS

DESIGNERS GUIDES TO:

- REAL-TIME SOFTWARE
- COMPUTER BUSES

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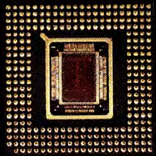

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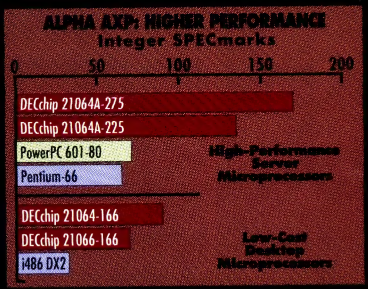

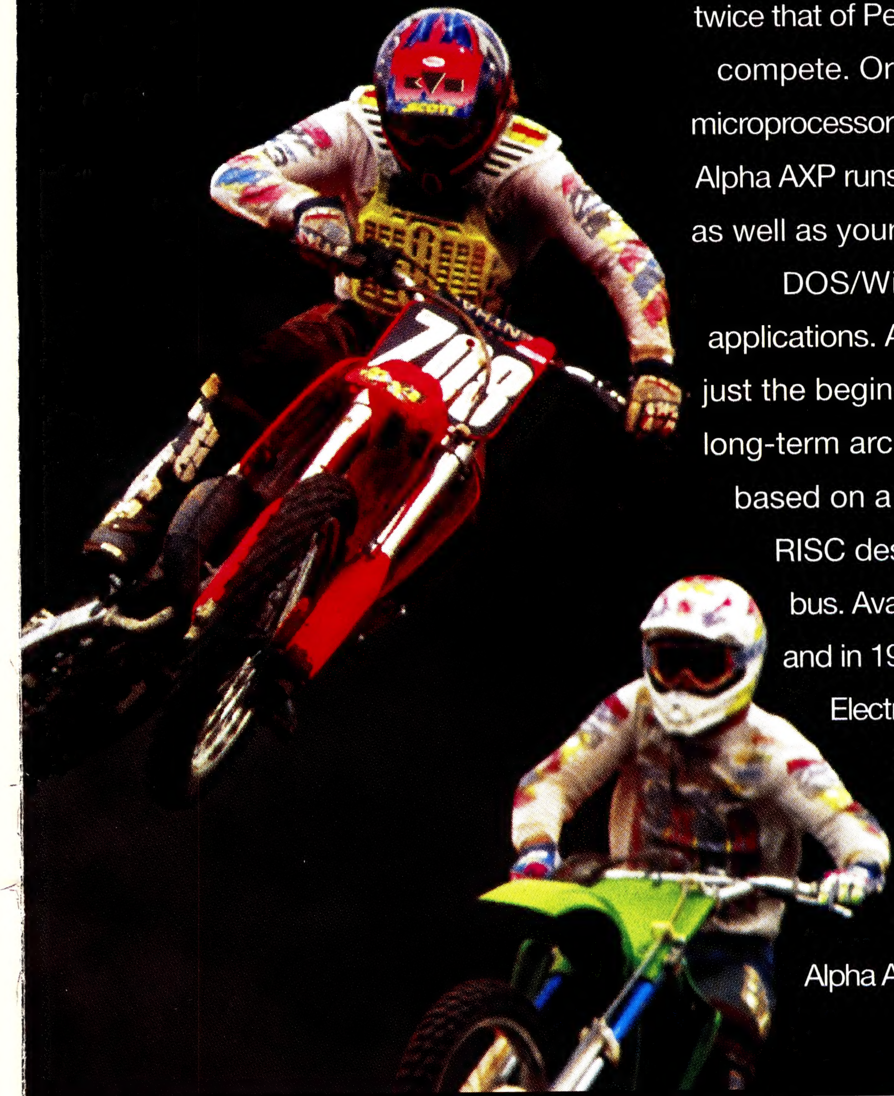

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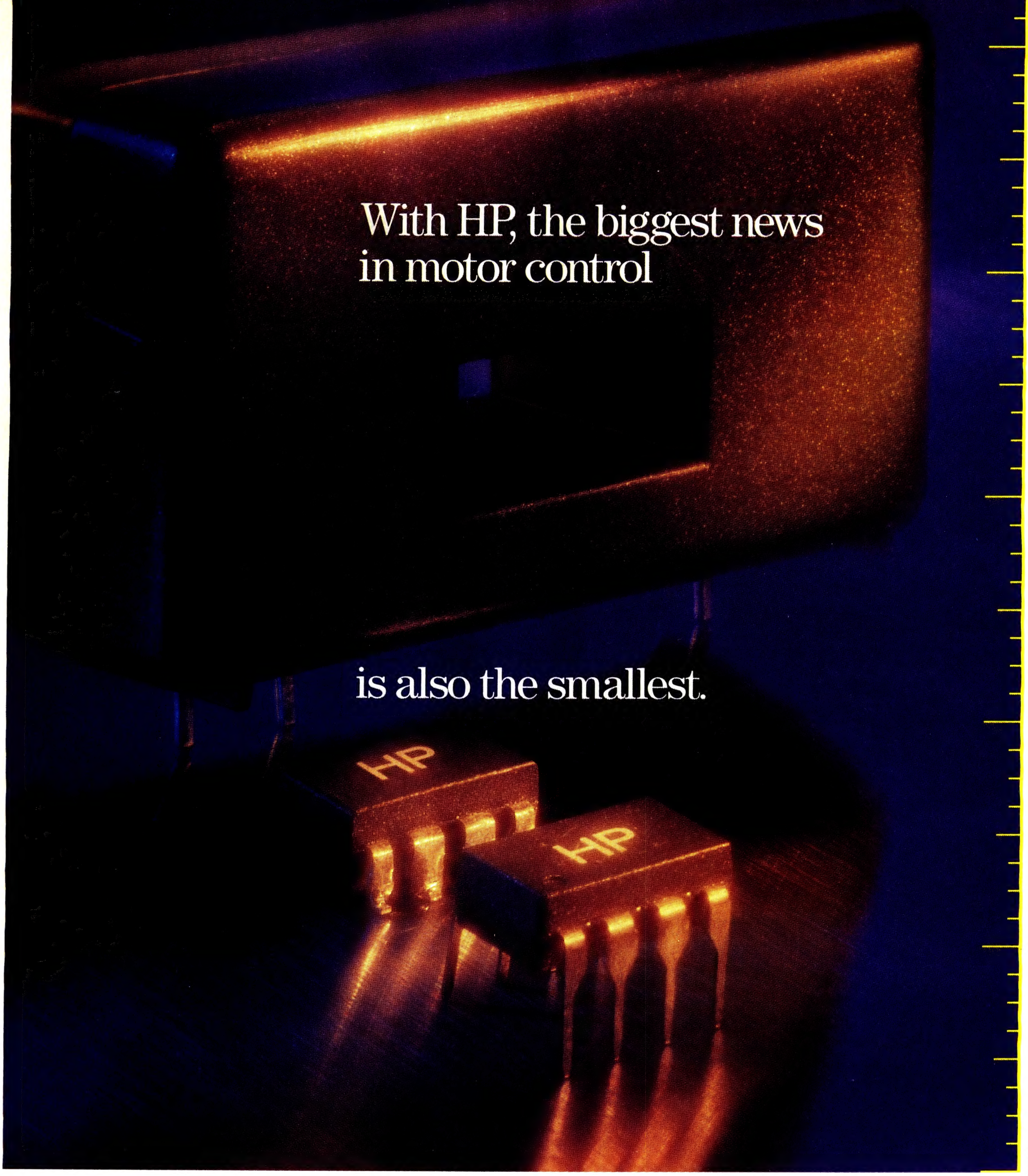

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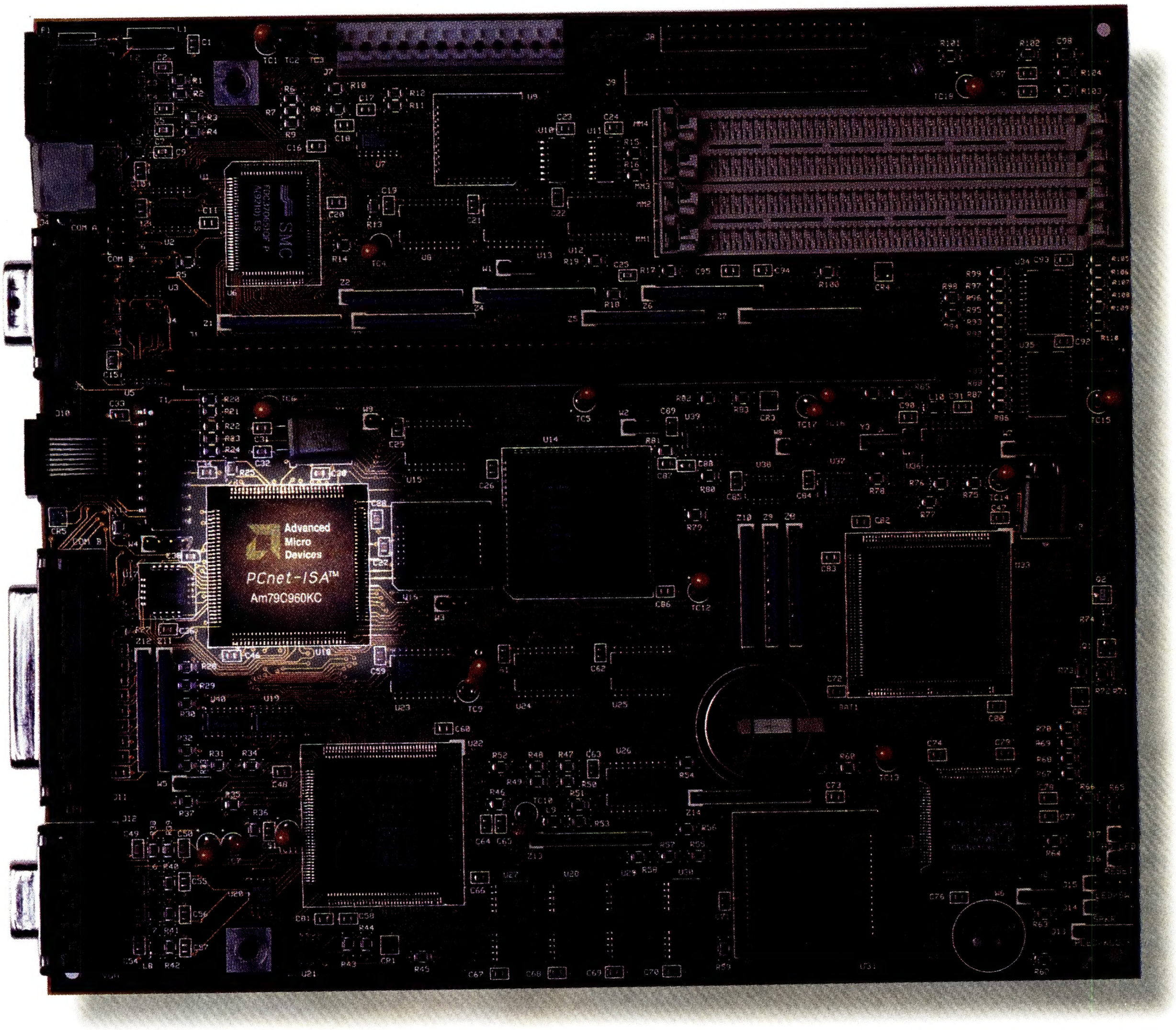

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NOVEMBER 22, 1993 VOL. 41, NO. 24

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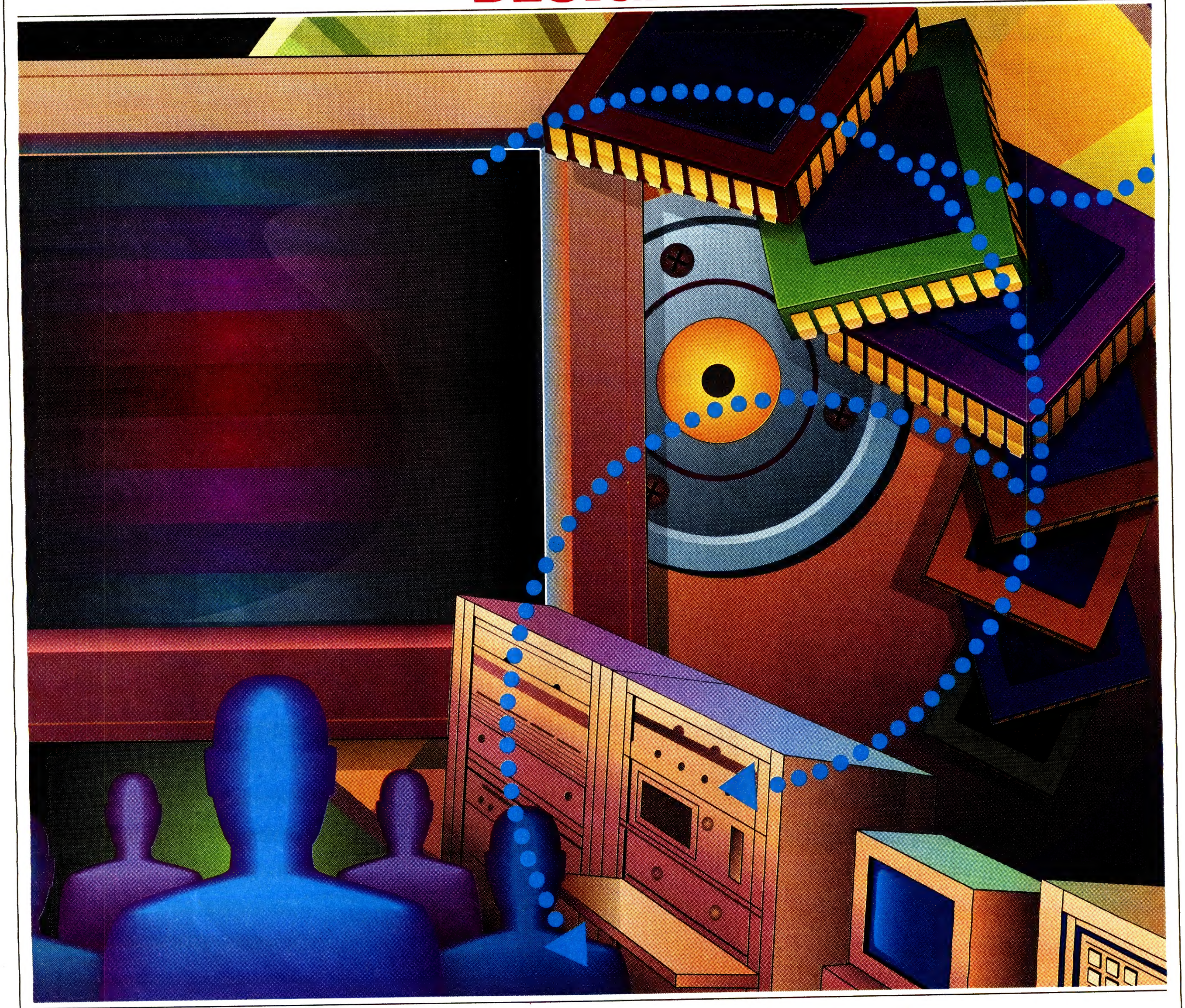

SPECIAL ISSUE ON COMPUTING: FEATURES

A LONG-RANGE LOOK AT THE WORKSTATION-PC MARKET . . . 29
The collision of cultures and products is shaping up with fierce competition.

COMPUTER DATA STORAGE: THE TRENDS AND HOT PRODUCTS . . . 57
Storage capacity continues its upward flight with a steady stream of improvements.

MICROPROCESSOR PERFORMANCE ONSLAUGHT PUSHES ON . . . 85
Enhanced caches and architectures are key driving forces.

A GUIDE TO REAL-TIME OPERATING SYSTEMS . . .115
The number of embedded applications continues to skyrocket, giving developers many operating systems to choose from.

A DESIGNER'S GUIDE TO COMPUTER BUSES . . . 129
Knowing the particular specifications for popular buses and interfaces is important in system design.

40
YEARS
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EXCELLENCE

VIEWPOINTS FROM COMPUTER INDUSTRY LEADERS

THE FUTURE OF THE PDA . . . 43
Gaston Bastiaens, Apple Computer Inc.

THE COMING OF THE PERSONAL WORKSTATION? . . . 44
William Jackson, Digital Equipment Corp.

NETWORKING VISION FOR THE 90s . . . 47
Randy Meals, Hewlett-Packard Co.

POWER COMPUTING COMES TO THE DESKTOP . . . 48
Phil Hester, IBM Corp.

WHAT THE FUTURE HOLDS FOR COMPUTER BUSES . . . 50
Ray Alderman, PEP Modular Computers Inc.

MULTIPROCESSING TO LEAD THE WAY . . . 52
Chuck Narad, Sun Microsystems Computer Corp.

DISK DRIVES STORE MORE IN LESS SPACE . . . 71
Michael L. Workman, Conner Peripherals Inc.

REAL-TIME AND EMBEDDED SYSTEM OUTLOOK . . . 72
Dr. Inder M. Singh, Lynx Real-Time Systems Inc.

OPENING NEW, UNTAPPED MARKETS FOR PCs . . . 77
Moshe Lichtman, Microsoft Corp.

WHAT'S IN STORE FOR EMBEDDED SOFTWARE . . . 78
Jim Ready, Ready Systems Inc.

THE NEW FRONTIER FOR DATA STORAGE . . . 80
Eli Harari, SunDisk Corp.

RECENT ADVANCES IN STORAGE TECHNOLOGY . . . 81
Amyl Ahola, Seagate Technology Inc.

REAL-TIME SOFTWARE TO GET MORE COMPLEX . . . 83
David N. Wilner, Wind River Systems Inc.

DIRECTIONS IN MOBILE COMPUTING . . . 101
K. C. Murphy, Advanced Micro Devices Inc.

THE KEY TO PERSONAL COMMUNICATIONS . . . 102
Rob Franzo, AT&T Bell Laboratories

x86 CPUs WILL CONTINUE TO REIGN . . . 105
Jerry Rogers, Cyrix Corp.

THE FUTURE OF PERSONAL COMPUTING . . . 107
Garth Hillman, Motorola Inc.

GROUP COMPUTING FACES MANY OBSTACLES . . . 108
Charlie Carinalli, National Semiconductor Corp.

FUTURE MEMORIES TO GET MORE BANDWIDTH . . . 110
Mike Farmwald, Rambus Inc.

A WORLDWIDE VISION OF MULTIMEDIA . . . 113
Kevin McGarity, Texas Instruments Inc.

Cover Illustration: Tony Vitolo

40 YEARS AGO IN ELECTRONIC DESIGN . . . 8
Miniaturized D-C power pack; Servo sub-assemblies: wide variety available

EDITORIAL . . . 14
Welcome to the Special Computing Issue

TECHNOLOGY BRIEFING . . . 18
NiMH battery standards move ahead

TECHNOLOGY NEWSLETTER . . . 23
- Complementary bipolar and CMOS come together
- III/V HEMT oscillator runs at up to 213 GHz
- Vendors agree to meld PCS technologies
- New ion-beam source may boost resolution
- Interactive TV may be just around the corner
- Benchmark measures X-Windows performance
- Dolby's AC-3 algorithm gains more advocates
- Silicon carbide hits 12.9 GHz for discretes

NEW PRODUCTS . . . 141

INDEX OF ADVERTISERS . . . 152

READER SERVICE CARD . . . 152A-B

COMING NEXT ISSUE:

- Special Report: Electronic-systems design automation
- New chip set adds functions to data/fax modems
- Test & Measurement Update: What's new in function generators
- Versatile PLDs aim at complex logic
- A preview of the 1994 IEDM

Jesse H. Neal Editorial
Achievement Awards:
1967 First Place Award
1968 First Place Award
1972 Certificate of Merit
1975 Two Certificates of Merit
1976 Certificate of Merit
1978 Certificate of Merit
1980 Certificate of Merit
1986 First Place Award
1989 Certificate of Merit
1992 Certificate of Merit

ELECTRONIC DESIGN (USPS 172-080; ISSN 0013-4872) is published semi monthly except for 3 issues in May and 3 issues in November by Penton Publishing Inc., 1100 Superior Ave., Cleveland, OH 44114-2543. Paid rates for a one year subscription are as follows: $95 U.S., $175 Canada, $255 International. Second-class postage paid at Cleveland, OH, and additional mailing offices. Editorial and advertising addresses: ELECTRONIC DESIGN, 611 Route #46 West, Hasbrouck Heights, NJ 07604. Telephone (201) 393-6060. Facsimile (201) 393-0204.

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WIRELESS

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PORTABLE COMMUNICATIONS PRODUCTS

With the demand for integrated data, graphics, voice and video transmission capabilities, designing products for the subscriber side of wireless will require IC-level products with wide data bandwidths, low power, CODEC capabilities and extremely high on-chip integration. And because of user location and wireless infrastructure limitations, satellite uplink capabilities will be required.

INFRASTRUCTURE

As the number of wireless users continues to grow, so also will the demand for seamless communications capabilities regardless of user location. This may require the development of multiple close-range microcells (<a few hundred meters) deployed around fast and flexible macrocell base stations. These base stations will need a great deal of computing power, bandwidth and software-driven intelligence.

DISTRIBUTION

In 1993, the U.S. FCC allocated portions of the 2GHz and 900MHz bands of the electromagnetic spectrum for PCS and narrowband PCS respectively. As spectrum allocation and usage continues, users will benefit from new, lower-cost services.

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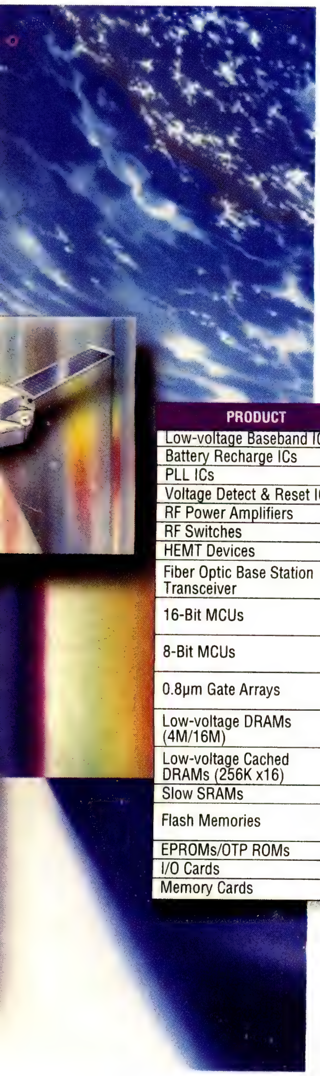
Across The Spectrum.



Wireless technology is permeating business and personal communications globally, driving portable product size and performance to totally new levels.

For OEMs, this means designing products that can operate across the spectrum. It means integrating more functions into single-chip solutions so that more features and applications can be designed into smaller and lower-power end products.

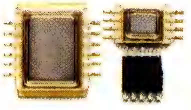
Mitsubishi has already begun RF integration onto single-chip GaAs MMICs for PCS applications, replacing 10 to 12 discrete components with a single, 3.4V transmitter device. We developed battery recharge ICs with 10-bit A/D accuracy and on-chip DSP; PLLs with on-board prescalers; and highly-integrated MCUs with 48KB ROM, 2KB RAM, I/O and a dot-matrix LCD controller on chip.

For microcell base station applications, Mitsubishi has integrated a laser diode, transmitter, receiver and support circuitry into a single, plug-and-play transceiver device.

Mitsubishi has also addressed the single-chip challenge by developing synchrotron-based production facilities to drive submicron silicon technology to the 0.25µm level and lower.

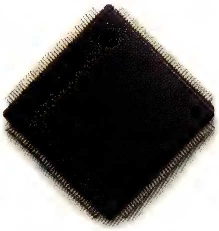
PRODUCT	Cordless/Cellular Phones (Analog & Digital)	Portable Storage	Mobile PCs/Terminals	Battery Monitor Control	PCN/PCS, WLANs, PDAs	Microcells	Wireless PBX	Global Positioning	FEATURES
Low-voltage Baseband ICs	◆								On-board Scrambler, Compander, Modem
Battery Recharge ICs	◆								10-Bit A/D Accuracy; On-chip DSP
PLL ICs	◆		◆		◆		◆	◆	Dual PLL Frequency Synthesizers
Voltage Detect & Reset ICs	◆								1.25V or 4.25V Detection
RF Power Amplifiers	◆		◆		◆	◆	◆		High Efficiency, Low Voltage, Surface Mount, Small Package
RF Switches	◆		◆		◆	◆	◆		Low Insertion Loss, Surface Mount
HEMT Devices								◆	High Gain, Low Noise, Surface Mount
Fiber Optic Base Station Transceiver						◆			900 MHz; Plug-and-play; Eliminates RF Blackout Areas
16-Bit MCUs	◆	◆	◆				◆		Up to 48KB ROM/2KB RAM or ROM-less, Very Low Power (4mA at 8MHz), Small Package
8-Bit MCUs	◆		◆	◆	◆				Up to 48KB ROM, On-chip Dot-matrix LCD Controller, 2.5V Operation
0.8µm Gate Arrays	◆		◆	◆	◆	◆	◆	◆	6K-250K Usable Gates, Clock Rates to 100MHz, 215 psec Delay, Low Power
Low-voltage DRAMs (4M/16M)		◆	◆		◆		◆	◆	3.3V, Self Refresh, Byte-wide
Low-voltage Cached DRAMs (256K x16)		◆	◆		◆		◆	◆	3.3V, Self Refresh, Byte-wide
Slow SRAMs	◆		◆		◆		◆		For Low-power, Battery-operated Data Storage
Flash Memories	◆	◆	◆		◆		◆		On-board Reprogrammability; For Code Storage, Data Storage,BIOS
EPROMs/OTP ROMs	◆	◆	◆		◆		◆	◆	Low Voltage, CLCC/TSOP Package
I/O Cards	◆		◆		◆			◆	Fax/Modem, LAN
Memory Cards	◆	◆	◆		◆			◆	DRAM, SRAM, Flash, Mask ROM

For more information on the wide range of Mitsubishi products for wireless, and to receive a free wall chart, *Guide to ICs and Components for Wireless Applications*, call **1-(800)-886-4088**



RF & Microwave Devices

3.3V DRAMs with enhanced power management for "green" projects



Mitsubishi MCU with on-board dot matrix LCD controller

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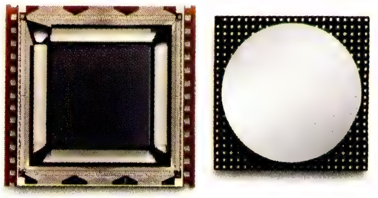

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ELECTRONIC DESIGN 40 YEARS AGO

Miniaturized D-C Power Pack

Transistorized equipment, guided missile circuits, computer units, and many other kinds of electronic devices, both miniature and standard sized electronics devices, can be powered by the "Transpac" units shown on the front cover and in Fig. 1. They are miniaturized d-c power packs, designed to be used as components in equipment. They save space, wiring, and weight, and provide a rugged, reliable, stable source of d-c power for a wide variety of electronic applications.

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Design features of these compact units include line isolation by means of an input transformer, bridge rectification using semiconductor diodes, use of selenium regulators, and high efficiency filtering. All units are in transformer type housings, and specially potted to resist shock and vibration. When required, they can be hermetically sealed and made to meet special commercial or military specifications.

Three of the many types available are shown in Fig. 1. The unit at the left is a constant voltage, 600cy, input-regulated, tubeless type designed for guided missile applications. Its size is 3" x 3" x 3-1/2"; input is 115v, 600cy; and the outputs are 30v and 150v, 25ma max. Ripple is less than 5 mv. The center unit is the 2" x 2" x 2" Model CC-15, a constant current source intended for supplying emitter bias in multi-stage transistor circuits. The input is 115v, 60cy, and the output provides five separate 1ma taps for feeding up to five separate stages. These taps can be interconnected to give either positive or negative current or a combination of both. The taps can also be combined to yield a variety of current values in 0.5ma steps from 0.5ma to 5ma max. Internal impedance of each tap is greater than 250,000 ohms, and there is negligible d-c interaction between taps. The a-c coupling between output taps is less than 5.0mmfd. The unit is line regulated for input variations of 95v to 135v a-c, and it weighs 14 oz. The unit at the right is a low internal impedance design for miniaturized i-f circuitry. Size is 1-1/2" x 1-1/2" x 2"; input is 115v, 400 cy; and output is 135v d-c at 20ma. Ripple is less than 15mv.

The units are made by Electronic Research Associates, Inc., 715 Main Street, North Caldwell, N.J. *(Electronic Design, November 1953, p. 21.)*

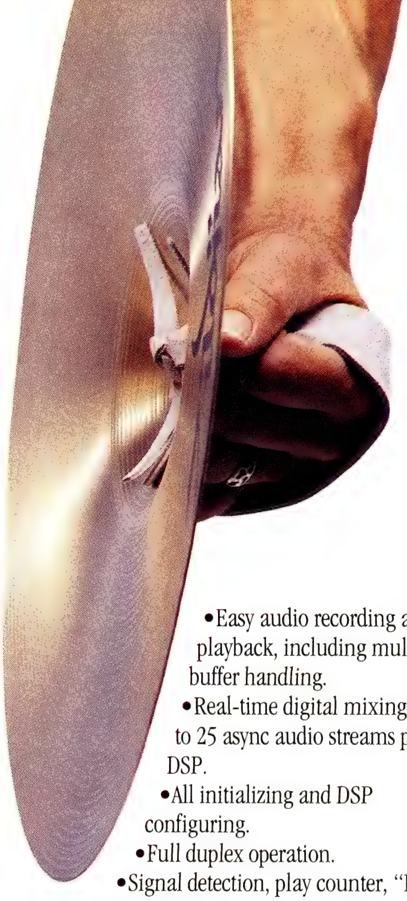
Military applications drove much of the solid-state revolution in the 1950s, and one of the first beneficiaries was the power supply, with its use of semiconductor diodes. An interesting sidelight: Note the 12-in. slide rule used in the photo for a size comparison. As was the case back then (and still holding true today), only the most familiar, everyday objects were used for that purpose.—Ed.

Servo Sub-Assemblies: Wide Variety Available

Sub-assemblies come in unlimited combinations, with newly designed motors, motor generators, gear trains and synchros. They combine precision servo system components into convenient, practical assemblies. A typical unit contains a Type 11M motor driving potentiometer, and a Type 11C synchro. Rotation of the potentiometer is limited by internal stops to 300°. The gear ratio between synchro and potentiometer is 2.5:1. The gears are protected by a slip clutch. Transicoil Corp., 107 Grand St., New York 13, N.Y. *(Electronic Design, November 1953, p. 38.)*

Servomechanism design was a high-profile topic 40 years ago. Plenty of component suppliers were in the business, and many EEs had to become intimately familiar with the mechanical characteristics of motors, clutches, and gears. For the up-and-coming EEs of that time, it was common to take a course in servo system theory, which focused on gain and phase analysis for feedback-loop stability.—Ed.

The Complete Audio Processing Solution for VME



Now you can get total control of your digital audio processing.

From voice to high fidelity music, for sound analysis, simulation, synthesis or communication processing, Vigra offers the most powerful and versatile audio systems ever available on the VMEbus.

Hardware. Four audio/DSP boards offer from one to four independent audio channels, and up to four 56001 DSPs. With on-board 16-bit A/D and D/A converters, CD/DAT quality audio is possible, limited only by the encoding and sampling rates which are under software control. On-board, multiported RAM, plus private DSP static memory, assure maximum audio thruput even with intense signal processing activity.

Vigra audio/DSP boards are used in the most demanding applications requiring the most reliable performance in 24-hour-per-day, year-in, year-out operation.

Software. Vigra's powerful DiSPATCH software system gives you an easy-to-use, high-level interface to the flow and processing of audio data, plus a full-featured tone generator for prompts, alarms and other synthesized sounds. With DiSPATCH, you'll have a firm handle on the complex procedure of encoding, decoding, storing, retrieving, mixing and manipulating audio signals.

DiSPATCH
Software Development Package

DiSPATCH is a four-part package consisting of a C Programming Library, a device driver, DSP firmware, and sample applications. DiSPATCH frees the host processor from the demanding real-time performance requirements of audio data control, and offers many valuable features:

- Format encoding for PCM-16, PCM-8, ADPCM, µ-Law, A-Law, and 16 kbps Vector Quantizing.
- Easy audio recording and playback, including multiple buffer handling.
- Real-time digital mixing of up to 25 async audio streams per DSP.
- All initializing and DSP configuring.
- Full duplex operation.
- Signal detection, play counter, "RAM to RAM" processing and other special features.
- Device drivers are available for most VME operating systems.

DiSPATCH *Tone Generator*

With the Tone Generator, the DSP can function as a versatile real-time tone synthesizer, generating sounds such as sirens, horns, beeps, buzzers as well as much more complex sounds. Built-in sine, triangle, sawtooth and square waveforms can be mixed with tones from arbitrary waveform tables supplied by the host. Variable-rate tone sweeps, two-tone sounds, programmable envelopes, and AM/FM modulation synthesis are supported. Tones can even be mixed with sampled audio tracks.

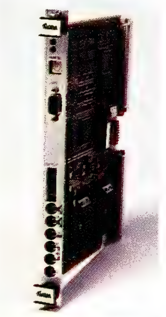
Custom Audio Products

Supporting Vigra's VME audio products and processing software is a highly talented, experienced engineering team—ready to help you translate your requirements into a sensible, economical and top-performing solution. Whether your needs are custom or standard, call us today and find out about Vigra.

If you work with sound, we speak your language.

The MMI-4211 has four mic and four line inputs, four output channels, four 56001 DSPs, 4M bytes of RAM, 16-bit A/D and D/A, and programmable output mixing.

The MMI-210 has two line inputs and outputs, plus speaker outputs, two 56001 DSPs, 4M bytes of RAM, 16-bit A/D and D/A, and A+B output mixing.



The MMI-110 is a dual-channel VME audio/digital signal processor board compatible with Silicon Graphics' SGI Audio Library.

The MMI-105 has mic and line inputs, a line output, a 56001 DSP, up to 8M bytes of RAM, and 14-bit A/D and D/A.

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What will Siliconix' new 3-V p-channel MOSFETs do to help shrink system size?

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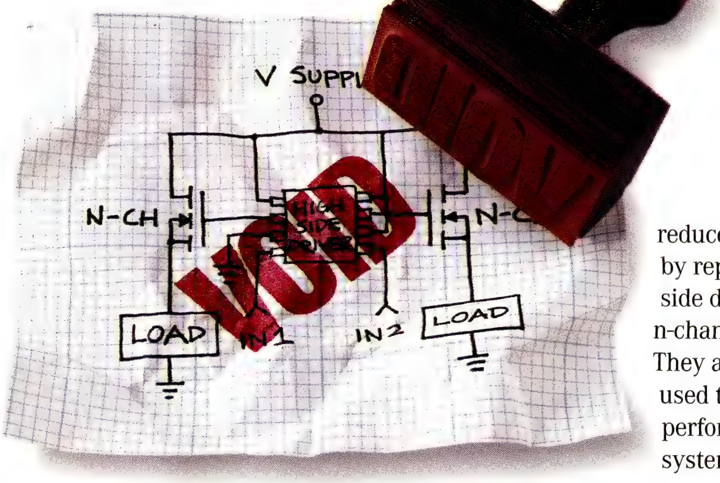

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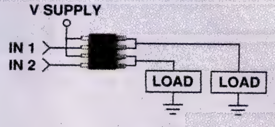

Device	Breakdown Voltage (V)	On-Resistance (Ω)	Current (A)
Si9433DY	-12	0.075 @ V_{GS} = -4.5V	±5.1
single p-ch	-12	0.110 @ V_{GS} = -2.7V	±4.0
Si9933DY	-12	0.13 @ V_{GS} = -4.5V	±3.8
dual p-ch	-12	0.21 @ V_{GS} = -2.7V	±3.0

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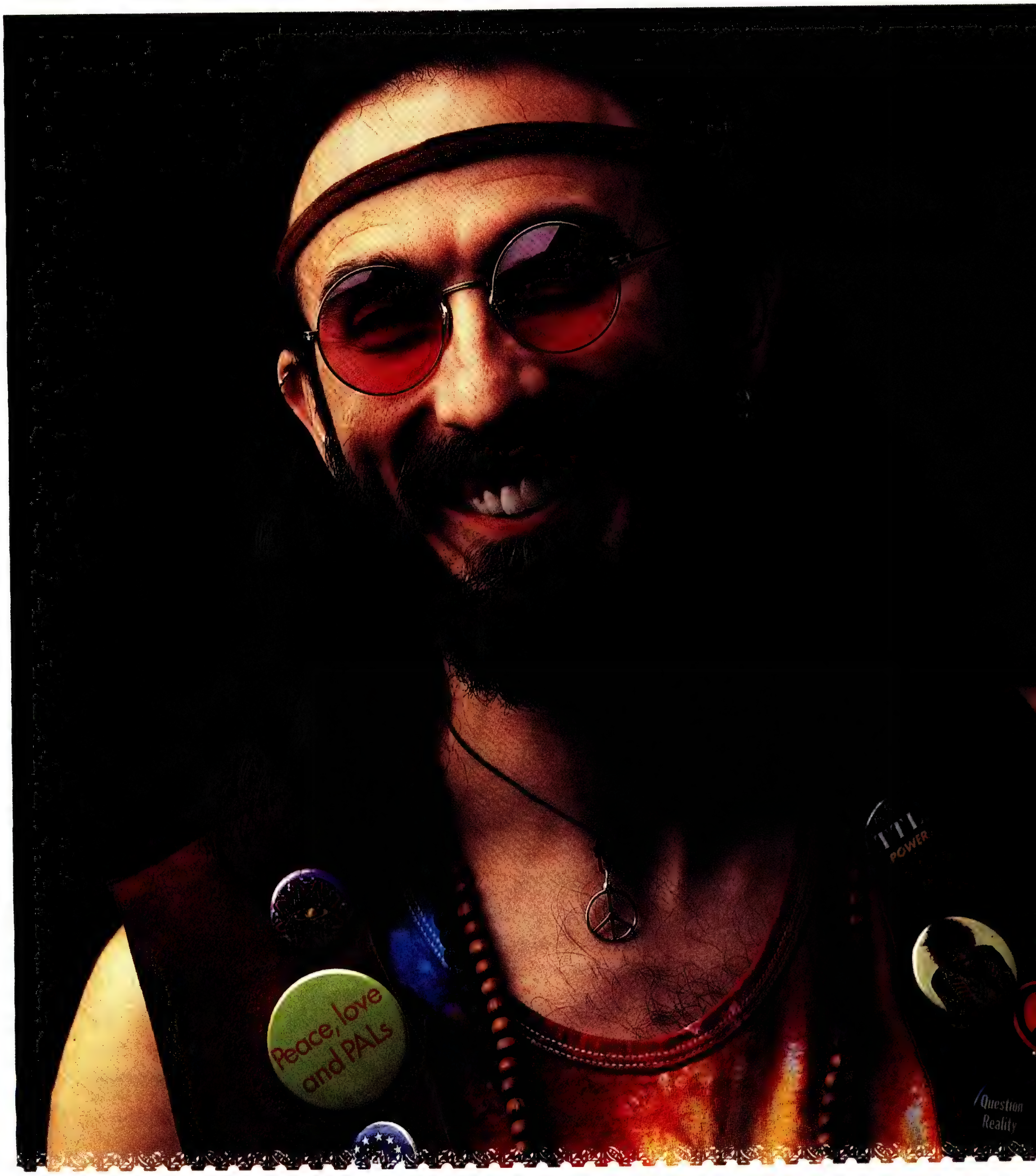

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Xilinx EPLD Benchmarks	
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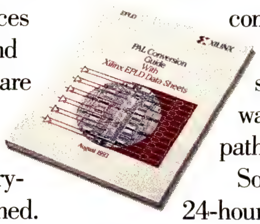

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WELCOME TO THE SPECIAL COMPUTING ISSUE

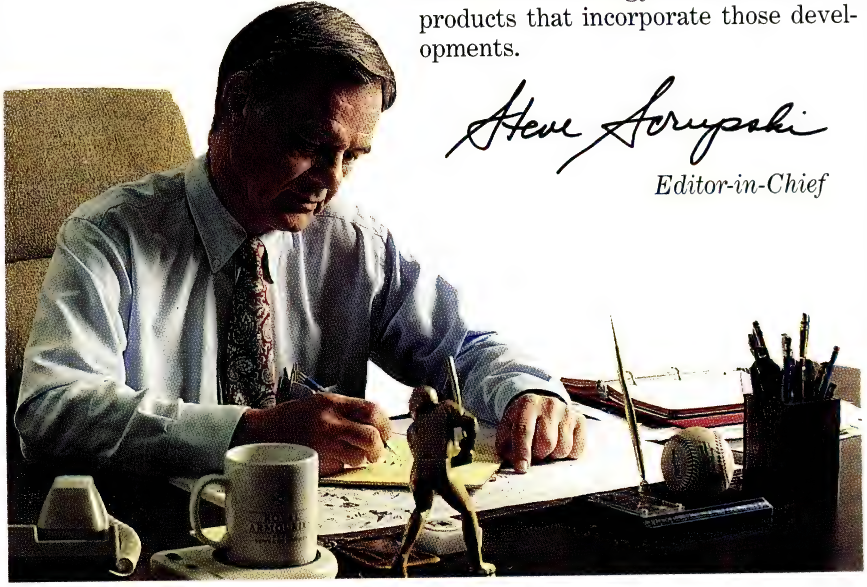
Regular readers of Electronic Design will notice that this issue is somewhat different: It concentrates on the subject of computing, the prime mover of the electronics industry since the invention of the microprocessor two decades ago. In a technology as fast-moving as computing, it's useful to occasionally pause and take stock of its progress, as well as reset our sights on future developments. This issue gives us an opportunity to do that—to go into depth with a variety of articles, presenting overviews on workstations, data-storage devices, and microprocessors, and roundups on computer buses and real-time operating systems.

The overview articles on workstations and storage peripherals are authored by two savvy computer-technology analysts, one from International Data Corp. and the other a former member of the Dataquest staff. The report on microprocessors is the work of Electronic Design's Digital Semiconductors Editor Dave Bursky, who has spent the past 15 years reporting semiconductor-industry developments from his base in Silicon Valley. The computer-bus and real-time software guides were compiled by our Computer Systems Editor Richard Nass and our Software Editor Sherrie Van Tyle, respectively.

Interspersed among the features are 20 one-page articles written by computer industry leaders covering the trends in the most dynamic segments of computing technology. In some ways, these one-page articles can be considered a symposium in print on the subject of computing. The invited authors include representatives from many of the top companies in each segment of the computer industry. For workstations, personal computers, and computer boards, we have spokespeople from such companies as Apple Computer, Digital Equipment Corp., Hewlett-Packard, IBM, Pep Modular Computers, and Sun Microsystems. In the various discussions on storage peripherals and software, we culled experts from Conner Peripherals, Lynx, Microsoft, Ready Systems, SunDisk, Seagate, and Wind River. The subject of high-performance CISC and RISC microprocessors is represented by AMD, AT&T Microelectronics, Cyrix, Motorola, National Semiconductor, Rambus, and TI.

One final note: To accommodate all of this material on workstations, personal computers, embedded controllers, software, and other topics vital to engineers engaged in the design of computing systems, we had to leave out some of our popular regular sections, such as Ideas For Design, Pease Porridge, QuickLook, and others. Fans of these sections can be assured of their return in our next issue, along with our usual exclusive reports on recent developments in basic electronic technology and the major new products that incorporate those developments.

Steve Scrupski
Editor-in-Chief



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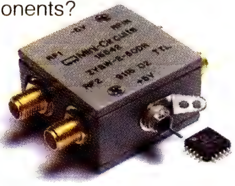

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Isolation (dB)	42	31	20	50	40	28
1dB Comp. (dBm)	18	20	22.5	20	20	24
RF Input (max dBm)	—	20	—	22	22	26
VSWR "on"	1.25	1.35	1.5	1.4	1.4	1.4
Video Bkthru (mV,p/p)	30	30	30	30	30	30
Sw. Spd. (nsec)	3	3	3	3	3	3
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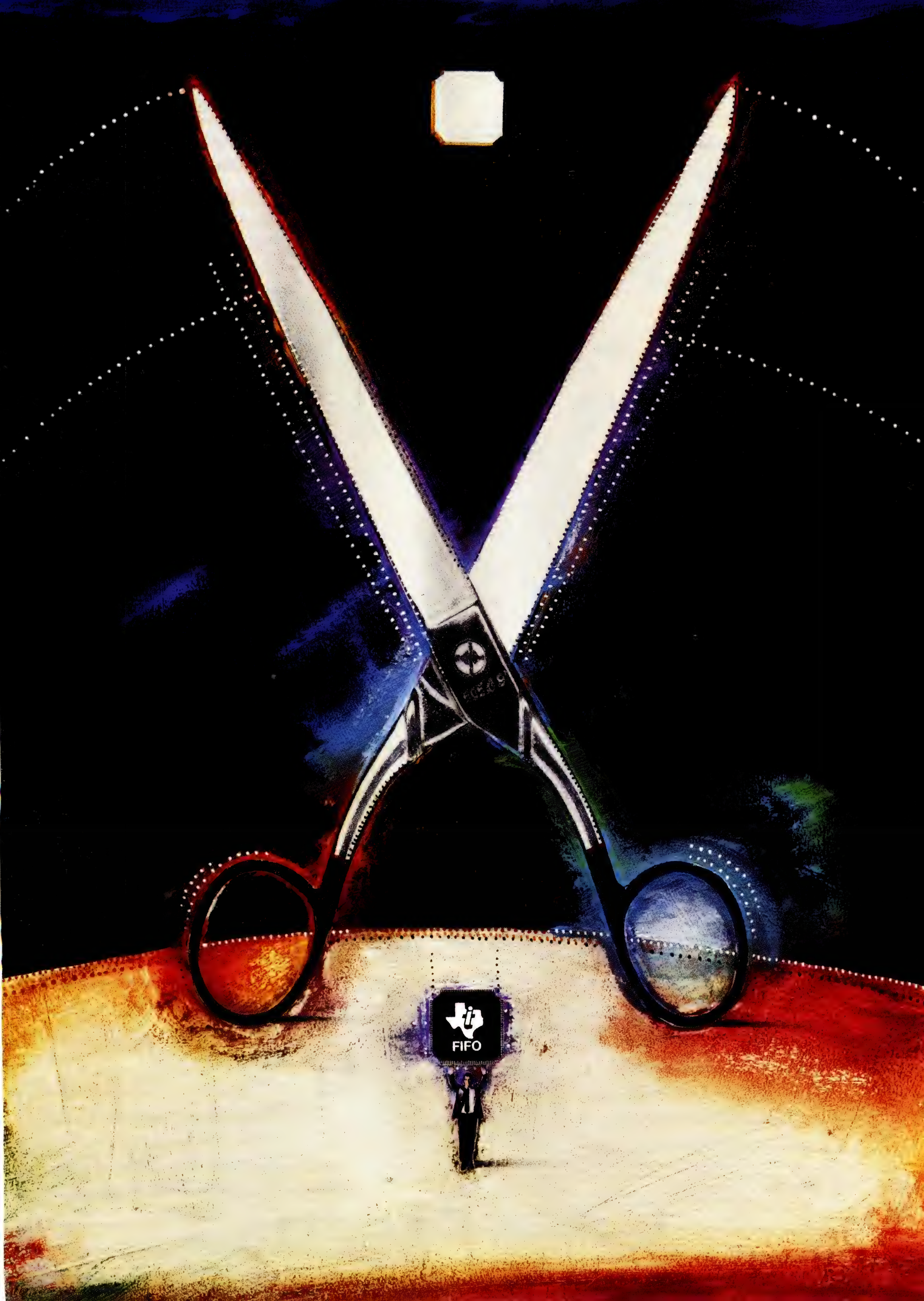

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CIRCLE 112 FOR U.S. RESPONSE
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NiMH Battery Standards Move Ahead

Visit just about any drugstore or supermarket and you'll find racks of alkaline batteries for your camera, portable tape player, flashlight, etc. The familiar AAA, AA, C, D, and 9-V cells that we all use represent a de facto standard in terms of the batteries' physical form factors. Now, think about the rechargeable battery packs for your notebook computer, handheld cellular phone, or camcorder. There's probably nothing at all standard about them. In fact, the pack for your computer or phone is in all likelihood a custom design, with all of the related time and cost implications.

Upon announcing its plans one year ago to launch a line of nickel-metal-hydride (NiMH) rechargeable batteries for the communications, computing, and camcorder markets, Duracell Inc., Bethel, Conn., simultaneously signaled its intent to shape standard form factors for the battery packs used in such equipment. A relatively small number of standard NiMH battery packs to choose from may mean simpler, shorter design cycles.

That plan got a significant boost when AMP Inc., Harrisburg, Pa., was enlisted to develop a standard battery interconnection. Such an interconnect resolves one of what Duracell sees as the four essential elements for standardization. A second element, battery energy capacities, is addressed by the four packs the company introduced for computers. Their capacities were arrived at through extensive consultations with OEMs.

DAVID MALINIAK
COMPONENTS & PACKAGING

The third standardization element, the physical form factor of the devices to be powered, is already naturally stabilizing as the computer and cellular-phone industries settle on a few basic machine geometries. The fourth element, communication between the battery pack and the system it powers, is an area Duracell is already prepared for: The packs are ready to accept an ASIC to be designed in later for intelligence features, such as on-line status indication.

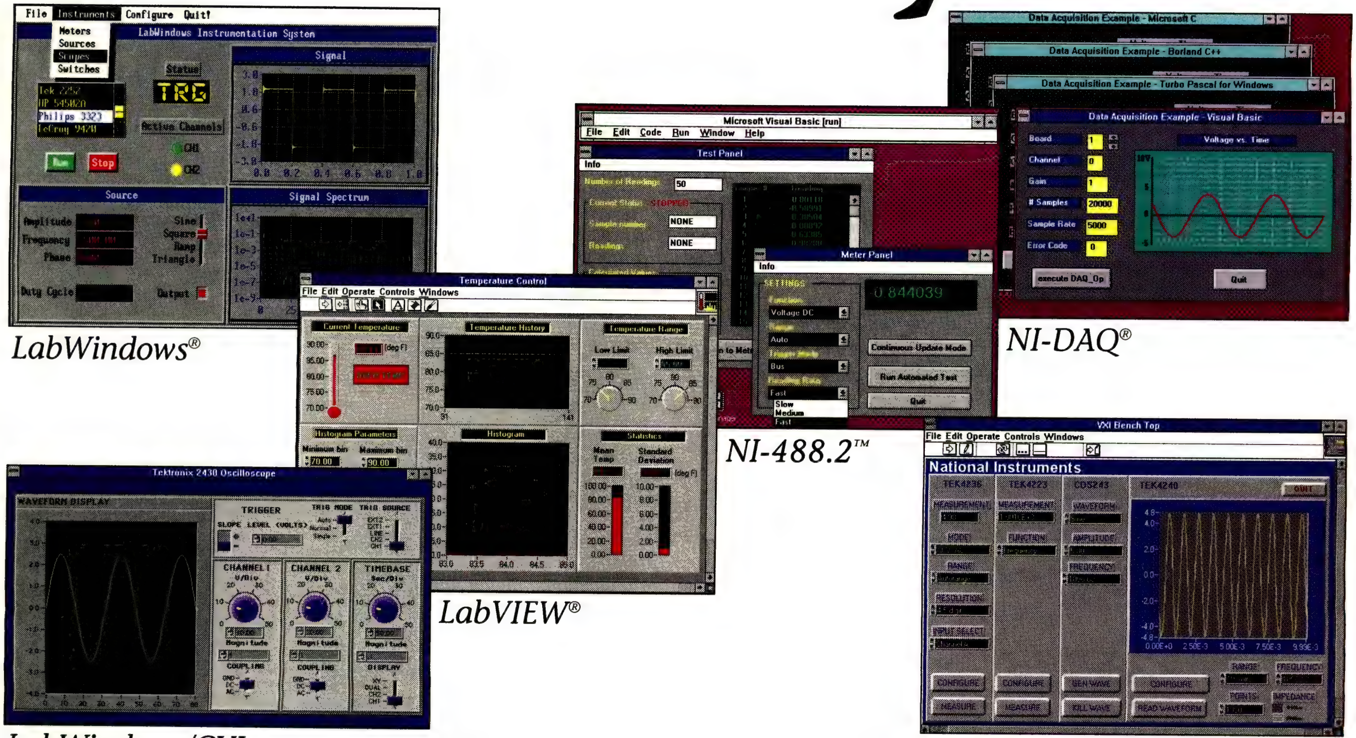
Although some intelligence will eventually be designed into the packs, questions remain as to how much active circuitry should be designed in. For example, one possibility is to partition charging circuitry in which some elements are placed inside the packs. The problem, of course, is that the packs' expected lifespan is about 1000 charge-discharge cycles, and it's debatable how much value should be designed into a device with a limited lifespan. Another direction could involve the development of a universal charger that will accept all standard packs, eliminating the need for multiple wall chargers.

The standardization of NiMH battery packs intends to combat the rapid proliferation of custom packs and, at the same time, establish a NiMH market for consumer electronics that more closely resembles the existing non-rechargeable (alkaline) market. According to Norm Allen, Duracell's vice president of new-product sales and marketing, establishing a small number of form factors as standards will make matters easier for OEMs, retailers, and consumers alike. Duracell is presently engaged in a technology alliance with Toshiba Battery Co. Ltd., Tokyo, and Varta Batterie AG, Hannover, Germany, in its efforts to establish standards.

Besides the previously announced intention of Fujitsu Network Transmission Systems Inc., Dallas, Texas, to use Duracell's NiMH packs in its next generation of cellular phones, Duracell has reaped at least one other major commitment to its standardized packs. According to Allen, Compaq Computer Corp., Houston, Texas, will use them in its next generation of notebooks.

With OEMs like Fujitsu and Compaq on board, as well as technical support from a supplier such as AMP and a partnership with Toshiba and Varta, the movement toward standardizing NiMH packs is quickly picking up steam. What remains to be seen is whether the concept will be as readily accepted as those blister-packaged alkaline cells we all know so well.

Meet Our Family.



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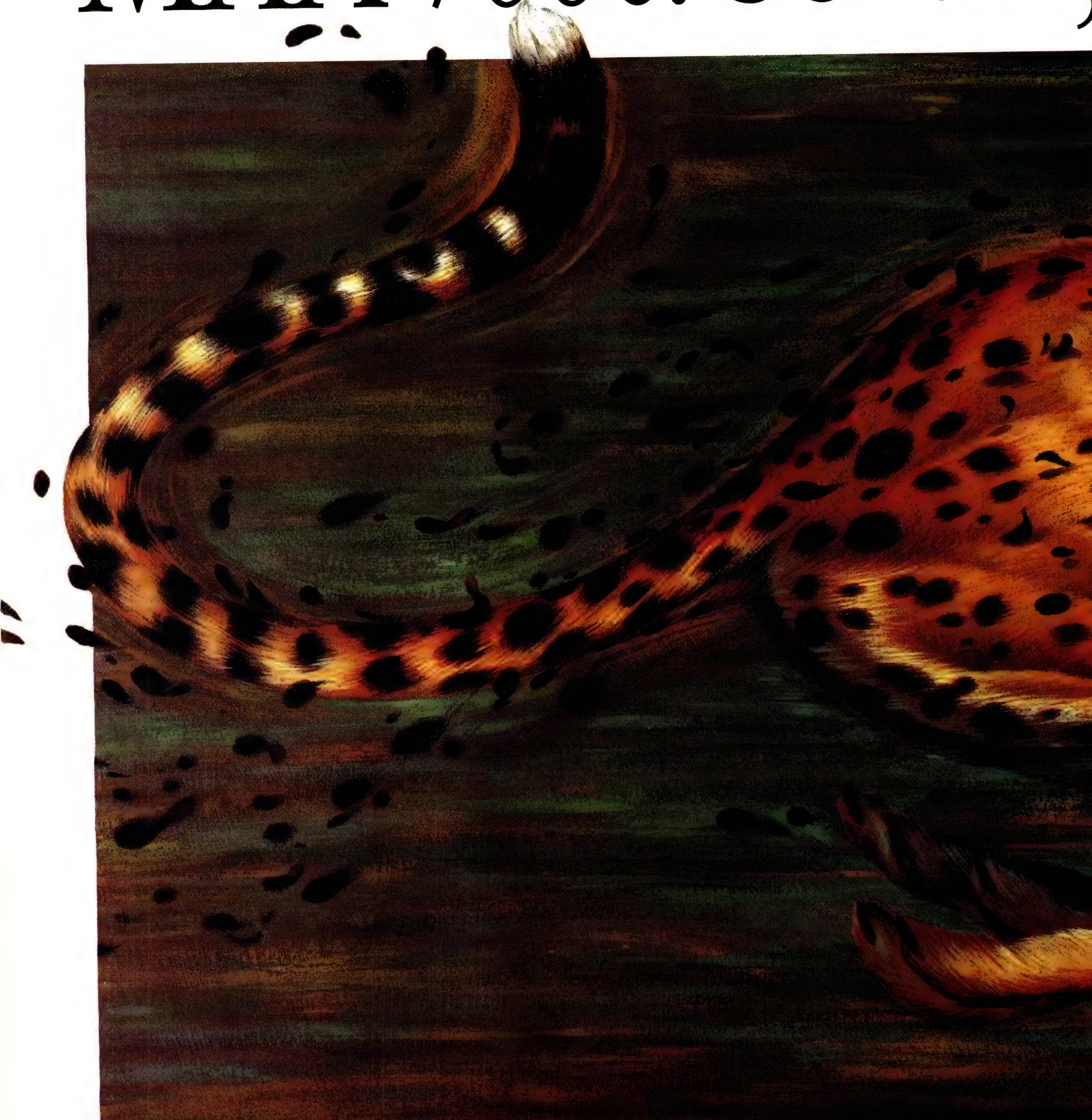

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TECHNOLOGY NEWSLETTER

COMPLEMENTARY BIPOLAR AND CMOS COME TOGETHER

A newly developed process will give designers the high-speed, low-distortion and low-noise characteristics of bipolar devices combined with the low-power benefits of CMOS and JFET structures. The CBiCMOS process, devised by Hughes Microelectronics, Newport Beach, Calif., puts complementary bipolar transistors onto the same substrate as CMOS circuits. The process integrates trench-isolated 5-GHz npn and 2-GHz pnp bipolar transistors with 2-µm CMOS gates. As a result, designers can create novel, high-integration circuits that will find applications in global-positioning system receivers, digital-cellular telephones, read/write-head amplifiers, ATE pin drivers, high-voltage automotive circuits, and high-definition TV. Matched complementary bipolar transistors in the process are suitable for differential amplifiers that have low distortion levels, wide dynamic ranges, high gains, and low output impedances. In addition, the process can be used in low-voltage applications, since circuits can be designed to operate from as little as 1.5 V. Hughes incorporated the process into a semicustom array that allows quick-turnaround designs with just four mask levels. Full-custom chips can also be built on the process. For more information, contact Patrick Kenaley at (714) 759-2934. *DB*

III/V HEMT OSCILLATOR RUNS AT UP TO 213 GHZ

Fabricated as a monolithic microwave/millimeter-wave IC (MMIC), a novel three-terminal device oscillates at fundamental frequencies of 155 to 213 GHz—the highest-frequency three-terminal oscillator reported to date. Employing III/V materials, the MMIC consists of aluminum-indium/gallium-indium-arsenide/indium-phosphide (AlIn/GaInAs/InP) high-electron-mobility transistors (HEMTs) that sport sub-0.1-µm gates made by electron-beam lithography. The oscillator's peak extrinsic transconductance is typically 1400 mS/mm (millisiemens per millimeter), and its extrinsic short-circuit current-gain cutoff frequency (f_t) extends to 330 GHz. Included on the oscillator are a slot antenna as well as a transmission line at the HEMT's gate and source terminals. It was developed by Hughes Research Laboratories, Malibu, Calif., and will be reported on at the upcoming International Electronic Devices Meeting (IEDM) in Washington D.C. Despite this high frequency, silicon devices aren't standing still either, as evidenced by an IEDM paper on heterojunction silicon-germanium transistors with f_ts above 100 GHz. Developed jointly by IBM, Yorktown Heights, N.Y., and Analog Devices, Norwood, Mass., the ICs are built on 8-in. wafers with a slightly modified silicon process. They have been used to build a 12-bit, 1-GHz DAC. For IEDM information, call (202) 986-1137. *FG*

VENDORS AGREE TO MELD PCS TECHNOLOGIES

Following the recent decision by the U. S. Federal Communication Commission to allocate frequencies for personal communications services (PCSs), Rockwell International Corp., Newport Beach, Calif., and Omnipoint Corp., Colorado Springs, Colo., agreed to collaborate in developing full-service PCS products. Under the agreement, Omnipoint's wireless spread-spectrum technology will be integrated with Rockwell's semiconductor and manufacturing expertise to provide high-performance, low-cost PCS subsystems. Omnipoint's prototype pocket telephones and base stations have been on trial with four regional Bell operating companies, four cable-TV providers, and several major prospective PCS providers. The system was demonstrated in cells from 100 ft. to 2.5 miles in diameter with hand-off at vehicular speeds of 65 mph. A single handset can be used in both the licensed bands for public PCSs and in the unlicensed bands for private applications, such as wireless PBXs. The two companies are pursuing the joint integration and delivery of both components and subsystems, ranging from chip sets and handsets to base stations. *ML*

NEW ION-BEAM SOURCE MAY BOOST RESOLUTION

A new type of ionization source that operates in a gas field may lead to focused-ion-beam (FIB) systems with resolutions comparable to that of a conventional scanning electron microscope. The gas-field ionization source (GFIS) would retain the ability of FIB systems to remove or deposit material, according to Bill Thompson, chief scientist at Micrion Corp., Peabody, Mass. He goes on to say that the less-massive ions from a GFIS may cause little or no sample damage. Micrion recently signed an exclusive license agreement for the GFIS technology, which was developed by S. Kalbitzer of the Max Planck Institute for Nuclear Physics in Heidelberg, Germany. Micrion says the new source, which is based on the Institute's gas-field ionization "Supertip" technology, can create

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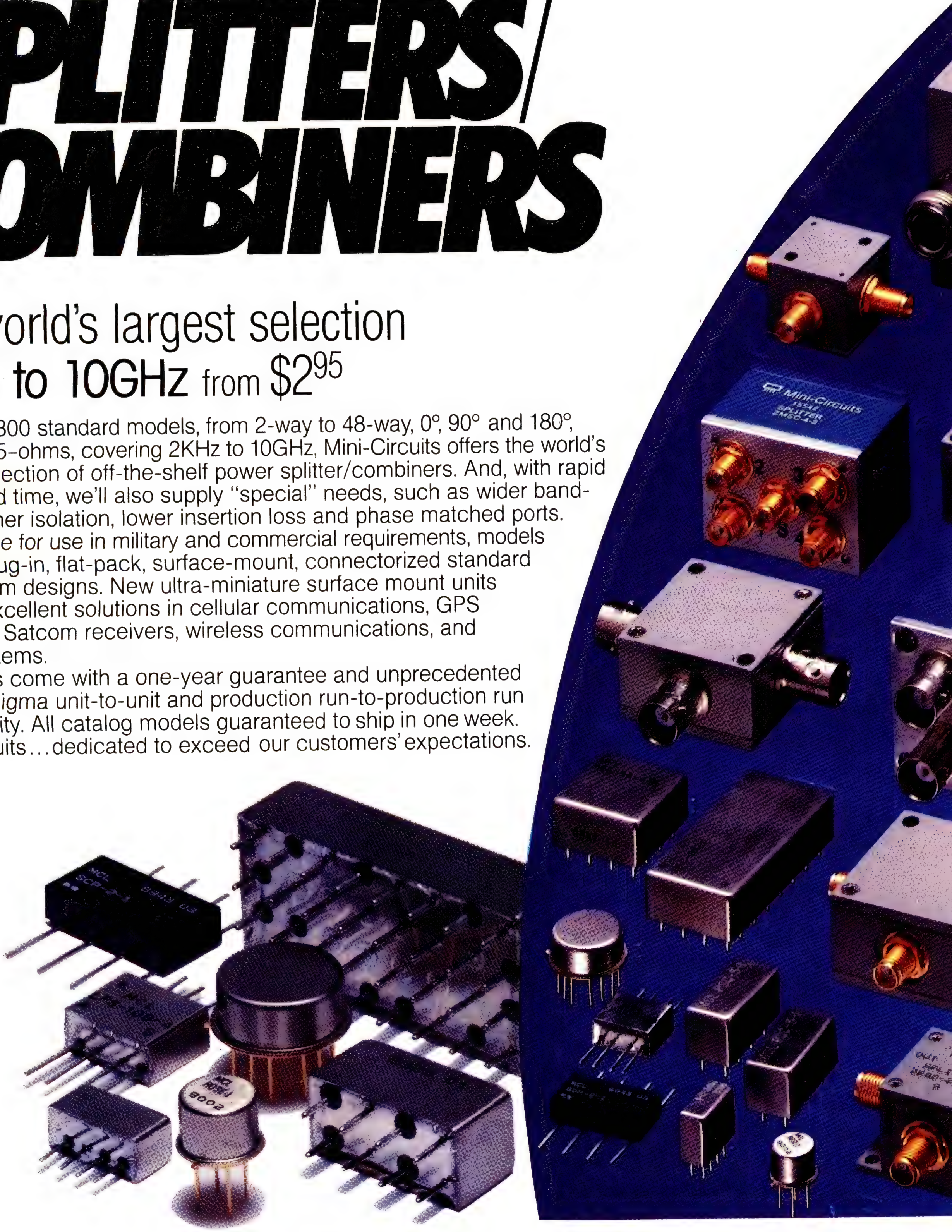

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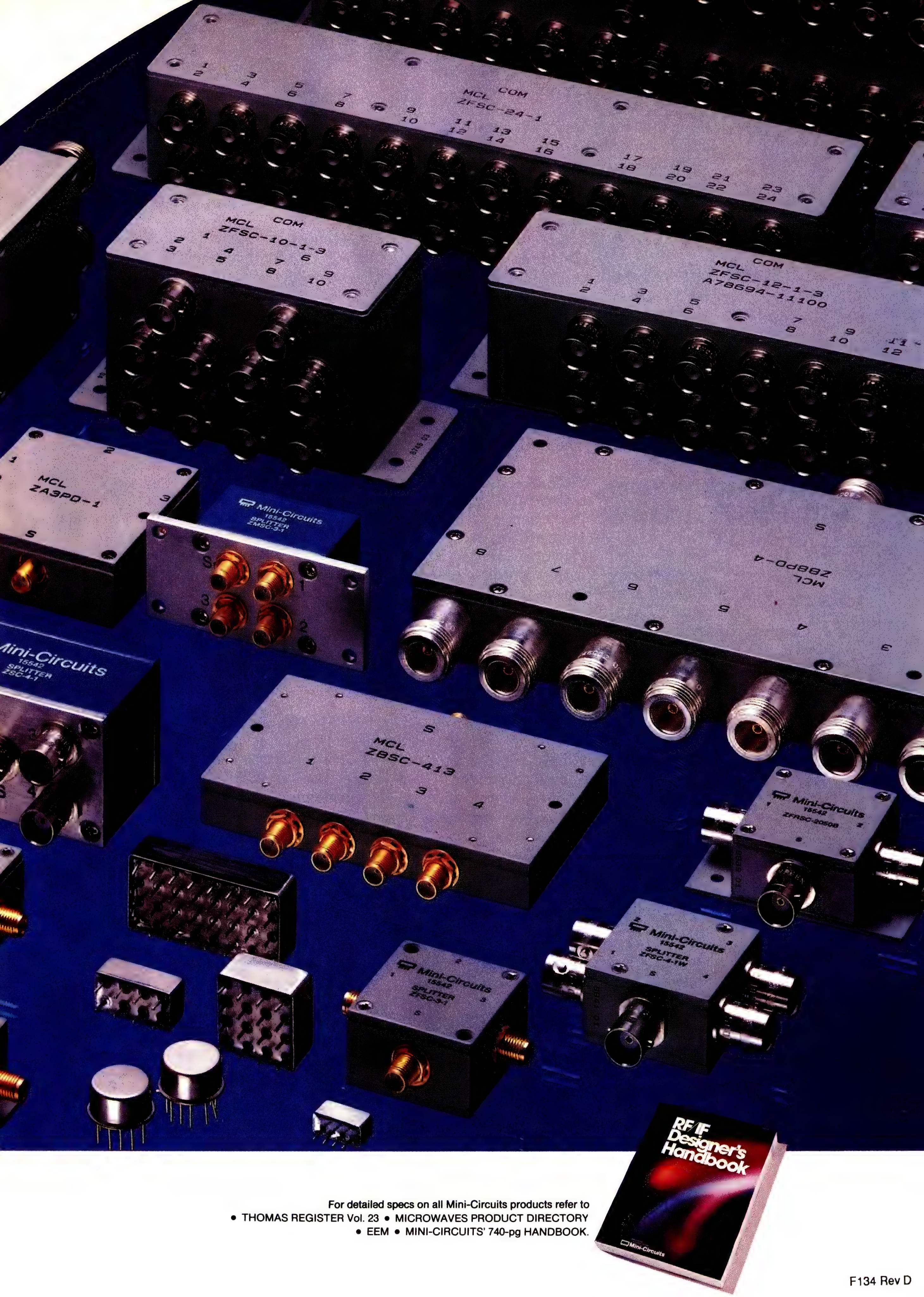

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beams 100 times brighter than today's liquid-metal ion sources. The GFIS operates in a gas ambient that supplies hydrogen, helium, neon, argon, or oxygen to be ionized and focused. The GFIS spot size is much smaller than conventional sources and higher current densities are possible. Micrion will experiment with the GFIS and plans to use it in systems for X-ray and phase-shift mask repair, circuit modification, failure analysis, and process monitoring. *JN*

INTERACTIVE TV MAY BE JUST AROUND THE CORNER

After four years of development, a control box will now enable TV sets to become fully interactive, regardless of whether they receive cable, broadcast, or satellite television transmissions. Designed to sit atop any standard TV set, the Interaxx Machine, devised by Interaxx Television Network Inc., Miami, Fla., will provide interactive entertainment, home shopping, video games, travel, and other services (such as video dating and acquiring tickets for sporting events). The box will include a built-in printer for printing out tickets, merchandise receipts, coupons, reservations, and confirmations. Basically, the viewer-operated, remote-controlled Interaxx Machine combines a CD-ROM, telephone modem, printer, and digital converter with the company's patented technology. Any form of TV transmission is suitable. The first TV systems will start carrying the Interaxx Television Network in early 1994, beginning with Channel America, which reaches 15 million homes, and Coral Springs Cable TV in Florida. *ML*

BENCHMARK MEASURES X-WINDOWS PERFORMANCE

Platforms operating in the X-Windows environment can be judged solely on their performance thanks to the Xmark93, a benchmark endorsed by the X Performance Characterization (XPC) group, Fairfax, Va. The benchmark, which supplies a standardized method of summarizing X11 results, handles a broad set of X primitives for a wide range of applications. The Xmark93 is derived by calculating the ratio between the geometrically weighted mean of the 447 individual X11 tests for the system being evaluated, and the corresponding results from a Sun Sparcstation 1 workstation. Weightings for the X11 tests were obtained by polling X11 technical experts. Work on additional X-Windows-related benchmarks is underway. The XPC group is governed by the National Computer Graphics Association (NCGA) and includes such companies as Apple Computer, Hewlett-Packard, IBM, Megatek, Network Computing Devices (NCD), Sun Microsystems, and Tektronix. The XPC group can be reached at (703) 698-9600. *RN*

DOLBY'S AC-3 ALGORITHM GAINS MORE ADVOCATES

A de facto standard is emerging in the fast-moving field of audio compression for five-channel surround-sound and other high-performance systems. Dolby Laboratories Inc.'s AC-3 algorithm was recently recommended as the proposed digital audio standard for U. S. high-definition TV (HDTV) by the Grand Alliance of companies developing the standard. Cable companies have also shown a great deal of interest in AC-3, which provides five channels of sound instead of the two delivered by today's stereo systems (ELECTRONIC DESIGN, *Oct. 1, p. 45)*. One reason the algorithm caught the attention of bandlimited applications is it's flexibility in being able to send five channels of compressed data over the two channels now reserved for stereo sound. This means that subscribers with Dolby Pro Logic receivers can reconstruct the five channels and listen to surround-sound. In the most recent AC-3 development, the San Francisco-based audio experts at Dolby licensed the algorithm to Texas Instruments Inc., Dallas, which plans to design and market a dedicated AC-3 chip for the consumer market by mid-1994. TI's part will have a digital-signal-processor core and borrow many of the function modules from its MPEG audio decoder. It will be fabricated initially in a 0.8-μm process. *JS*

SILICON CARBIDE HITS 12.9 GHZ FOR DISCRETES

A joint development project has yielded the highest-frequency FETs fabricated in silicon-carbide technology. Manufactured by Motorola Inc., Phoenix, Ariz., on 4H silicon-carbide (SiC) wafers from Cree Research, Durham, N.C., the devices operate as high as 12.6 GHz. SiC microwave FETs have been sought for a number of years because they can operate at high temperatures, and therefore they can function at 400 to 500% higher power levels than equivalent silicon or gallium-arsenide transistors. Making the high-frequency operation possible is the new 4H wafer material developed by Cree, which has a higher electron mobility than the company's original 6H SiC wafers. Motorola's role included collaboration on the design of the transistors, as well as fine-line electron-beam lithography and fine-dimension processing. Potential applications include industrial and military communications; cellular-telephone base stations; high-power solid-state broadcast systems; radar search-and-detection systems; and electronic countermeasures. Contact Cree at (919) 361-5709. *DB*

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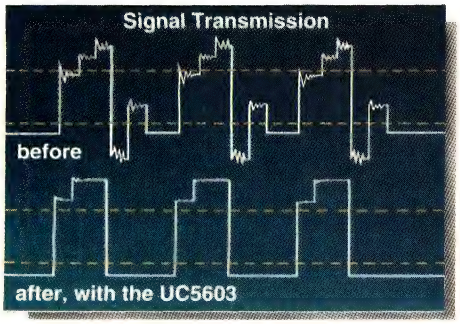

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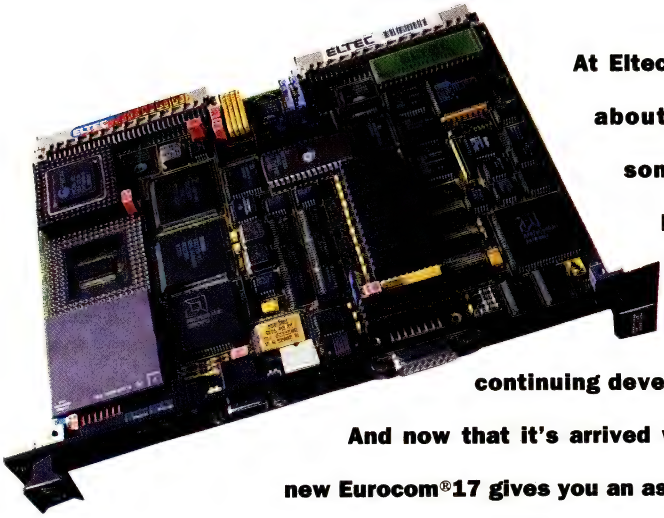

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A LONG-RANGE LOOK AT THE COLLISION OF CULTURES AND PRODUCTS

THE WORKSTATION-PC MARKET IS SHAPING UP WITH FIERCE COMPETITION.

BY NANCY C. BATTEY

MERELY A DECADE AGO, A WORKSTATION WASN'T JUST CALLED a workstation. It was given a more specialized name: an "engineering workstation" or a "technical workstation" or even more specifically, a "technical engineering workstation." Since then, the term has taken on a broader meaning, just as the systems themselves have evolved with enhanced feature sets and more functionality to handle broader applications.

The basic definition of what we call the workstation was formed by Apollo Computer, the pioneer in workstations (in 1989, it became a part of Hewlett-Packard Co., Palo Alto, Calif.). Very loosely, that definition starts with a high-performance CPU intimately coupled with a graphics subsystem and network communications. In the case of the Apollo hardware, that combination consisted of a Motorola 68000-family CPU that executed about 1 million instructions per second, a graphics system that could draw tens of thousands of vectors/s, and an Ethernet interface that transferred 10 Mbits/s. Local storage subsystems weren't very large in the early 1980s, and thus using LANs to provide a central storage resource was key to the viability of the early machines.

Systems have evolved from the early 1-MIPS $50,000 monochrome boxes to today's 50-MIPS, million-vector/s systems with color graphics and multimedia capabilities ranging in price from about $5000 to $250,000. Although the MIPS rating was used as a comparison point through the end of the 1980s, the new benchmarks that provide a more balanced performance rating are quoted in terms of SPECmarks, with the latest revision based on the 1992 update to the SPEC test definition. Thus today's system ratings are specified in terms of integer and floating-point SPECmarks (SPECint92 and SPECfp92).

This article, which discusses the emerging competition between workstations and personal computers, is authored by Nancy E. Battey, Director of Workstation Research at International Data Corp., Mountain View, Calif. Battey has specialized in the markets and technologies for workstations and PCs for a number of years. Dave Bursky, Electronic Design West Coast Executive Editor, also contributed to the article.

The high cost of the early workstations turned them into departmental resources that were typically shared between several users. The steep decline in system prices changed that business model to a one person/one machine (or in some cases one person/multiple machine) model. However, the picture has been "muddied" somewhat due to the increasing capabilities of personal computers (both x86- and 68 k-based), which give them performance levels comparable to some previous-generation workstations. Not surprisingly, though, the trend is that the two types of computer systems are converging, creating a new term, the "personal workstation."

The users of such systems are also changing. In the early 1980s, the dominant user was an engineer or research scientist; today such people make up a decreasing percentage of the total user base. That has been happening because new users, attracted to workstations because of their computational and graphics throughput, have replaced terminal-based systems or personal computers with RISC-based systems. The new user bases include such areas as financial analysis, stock trading, animation, desktop publishing, and many other applications.

In the early 1980s, International Data Corp. identified workstations as "PCs"—i.e., single-user, not multi-user systems. In the dozen years since that categorization, the single-user PC market has remained highly fragmented with respect to operating system, level of functionality, and price band. Even though an x86-based PC, Apple Macintosh, or Unix workstation could conceivably be used by the same individual, the fact remained that user buying behavior and usage patterns kept Unix workstations, until recently, in a class by themselves.

In 1993, two specific product events and two ongoing industry trends have coalesced to blur the distinction between workstations and PCs: In the product area, operating systems now are available for various hardware platforms. And coming up from the PC world, the Intel Pentium has reduced the gap in performance with RISC processors. The two industry trends contributing to this activity include the Unix workstation vendors who are eying the larger volumes of the desktop market and trying to provide the ease-of-use and lower price points of PCs and Macs. Secondly, PC vendors, taking note of the functionality and perceived higher margins of workstations, are looking to add performance and functionality (better graphics, built-in network interfaces, etc.) to their systems to improve their margins.

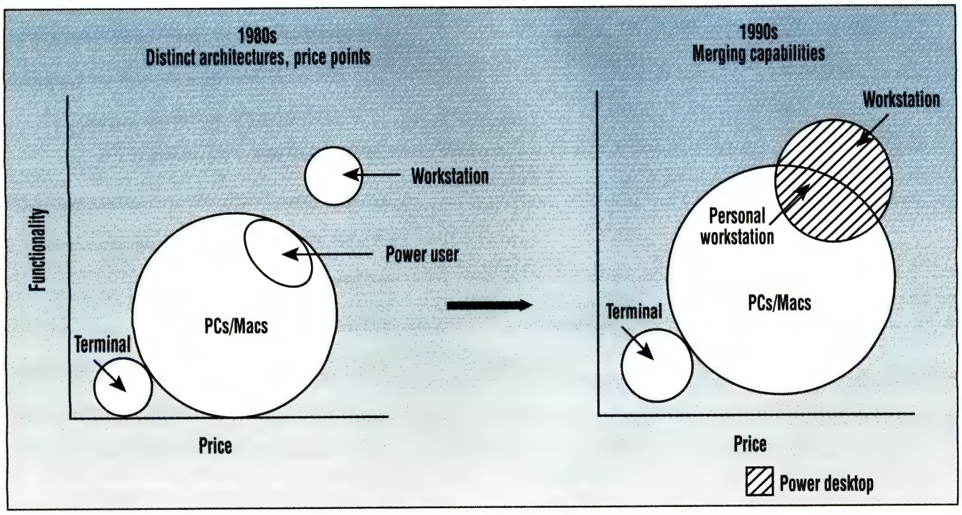
The result is a collision of cultures and products in the $4000 to $10,000 price range—a collision that will ultimately benefit users looking for the best combination of easy-to-use powerful systems at the right price point. Essentially, the personal-workstation segment will be an area of intense competition, leading to fierce price wars and performance battles *(see the figure)*.

One key feature distinguishing workstations from PCs is the operating system. Workstations typically possess both full-featured operating systems that allow multitasking program execution and integrated communications (networking). PCs, on the other hand, rely on DOS, which is a single-tasking operating system that doesn't include communications capabilities. Similarly, most Macintosh users only had a single-tasking OS without integrated communications.

Operating systems, such as Microsoft's Windows NT and IBM's OS/2, as well as the Macintosh OS version 7, now incorporate multitasking and some communications-aware features. Additional operating systems originally designed for workstations—Sun's Solaris 2.0 and NeXT's NeXTStep, for instance—are being ported to both RISC- and x86-based platforms. That blurs the traditional way of distinguishing a system, which is by the type of OS it runs.

Tied to the operating environment are the applications, which traditionally brought a technical focus to the workstation platforms and a business/clerical focus to the PC platforms. This difference also has dissolved—high-end PCs can run many of the complex technical packages, while a number of popular PC- and Macintosh-based office programs (word processors, spreadsheets, etc.) have been rewritten to run on RISC-based platforms. That virtually does away with any means to distinguish platforms.

Furthermore, prices of RISC-based systems are tumbling while the performance of pentium-based computers is on the rise. Again, such a trend will soon leave little price or performance differentiation between platform types. Today, platforms can still be distinguished based on processor, operating environment, and typical price band. As envisioned by IDC, the traditional PC will continue to be characterized by PC operating systems (namely DOS, OS/2 and MacOS); a typical price band of under $3000; and an education and home/hobby market focus.



Improvements in power, functionality, and price have given users more options in their choice of desktop equipment. In the 1980s, power users were restricted to employing either the upper edges of the personal-computer envelope, or workstations, which were significantly higher in price. In the 1990s, the merger of workstations and personal computers at the upper performance levels has produced a larger number of systems to select from, and with a varied range of performance levels. Terminals remain restricted to low functionality at low prices.

The traditional workstation will continue to represent the upper end of the PC segment in terms of features, functionality, and price. More specifically, it will continue to be defined by an advanced operating system (such as Unix, VMS, or newer types) and a typical price band of between $12,000 and $20,000. It will also home in on the technical market, even though roughly 25% of those shipped today are used for commercial applications *(Table 1)*. Examples of such systems include the Sun Sparcstation 10, the IBM RS/6000 family, the Hewlett-Packard Series 700, the Digital Equipment AXP workstations, the Silicon Graphics Crimson for Indigo, and others.

The personal workstation category, as IDC has defined it, represents the convergence of workstations' functionality, features, graphics, and distrib-

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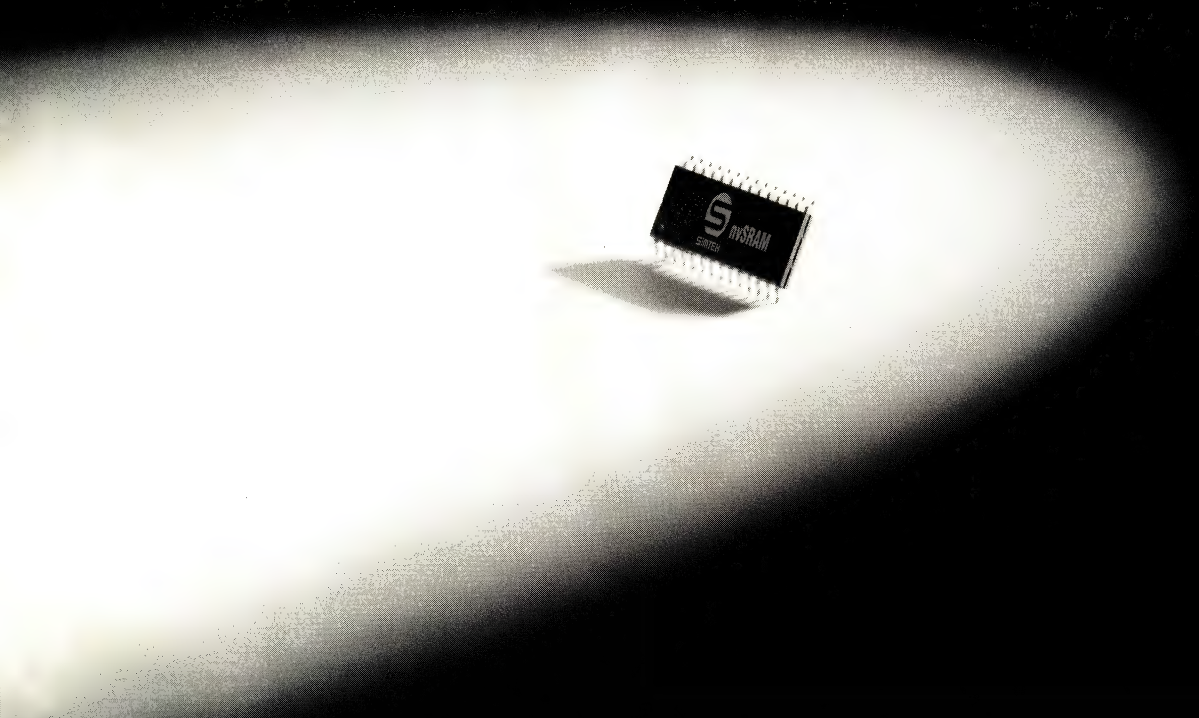

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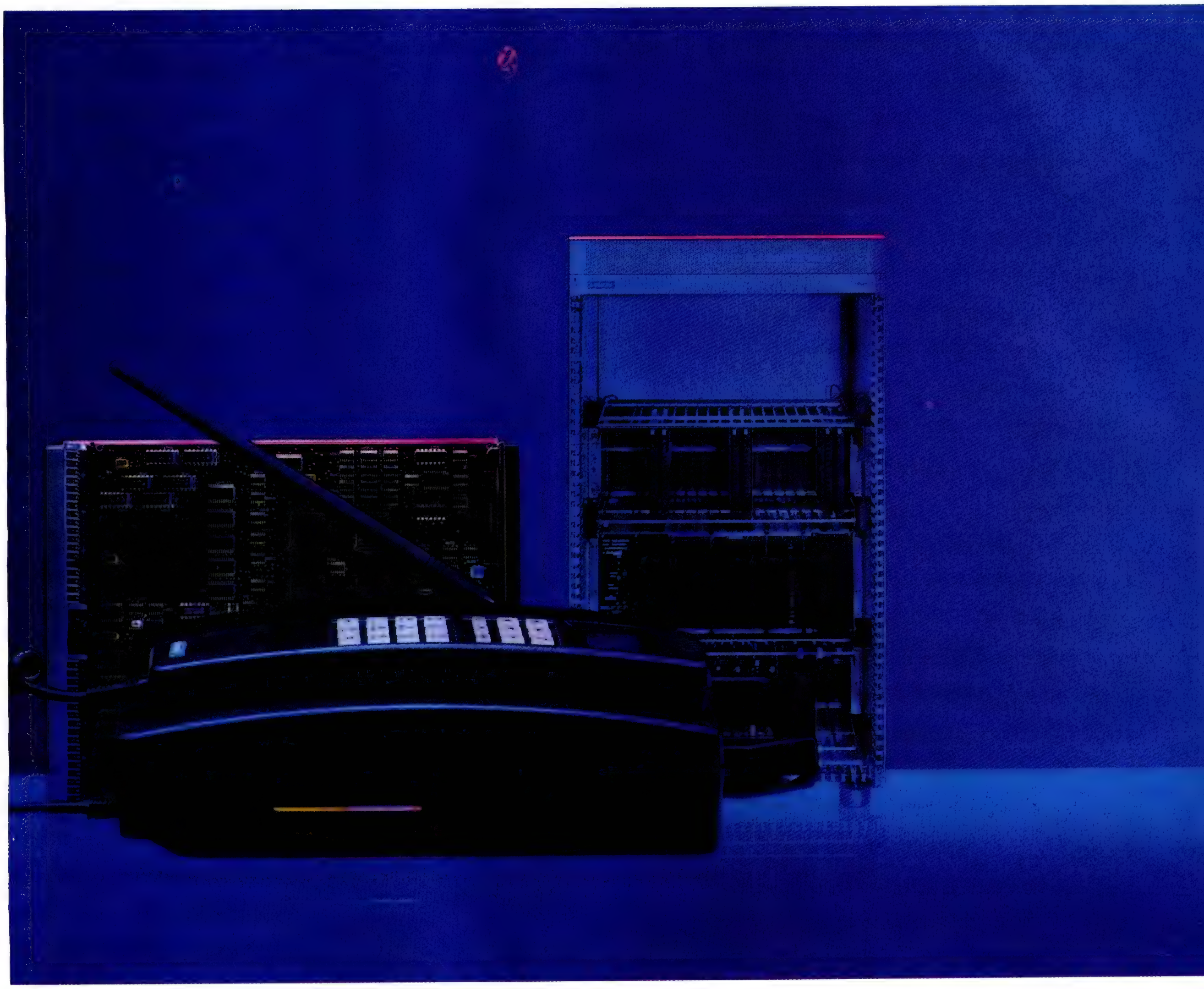

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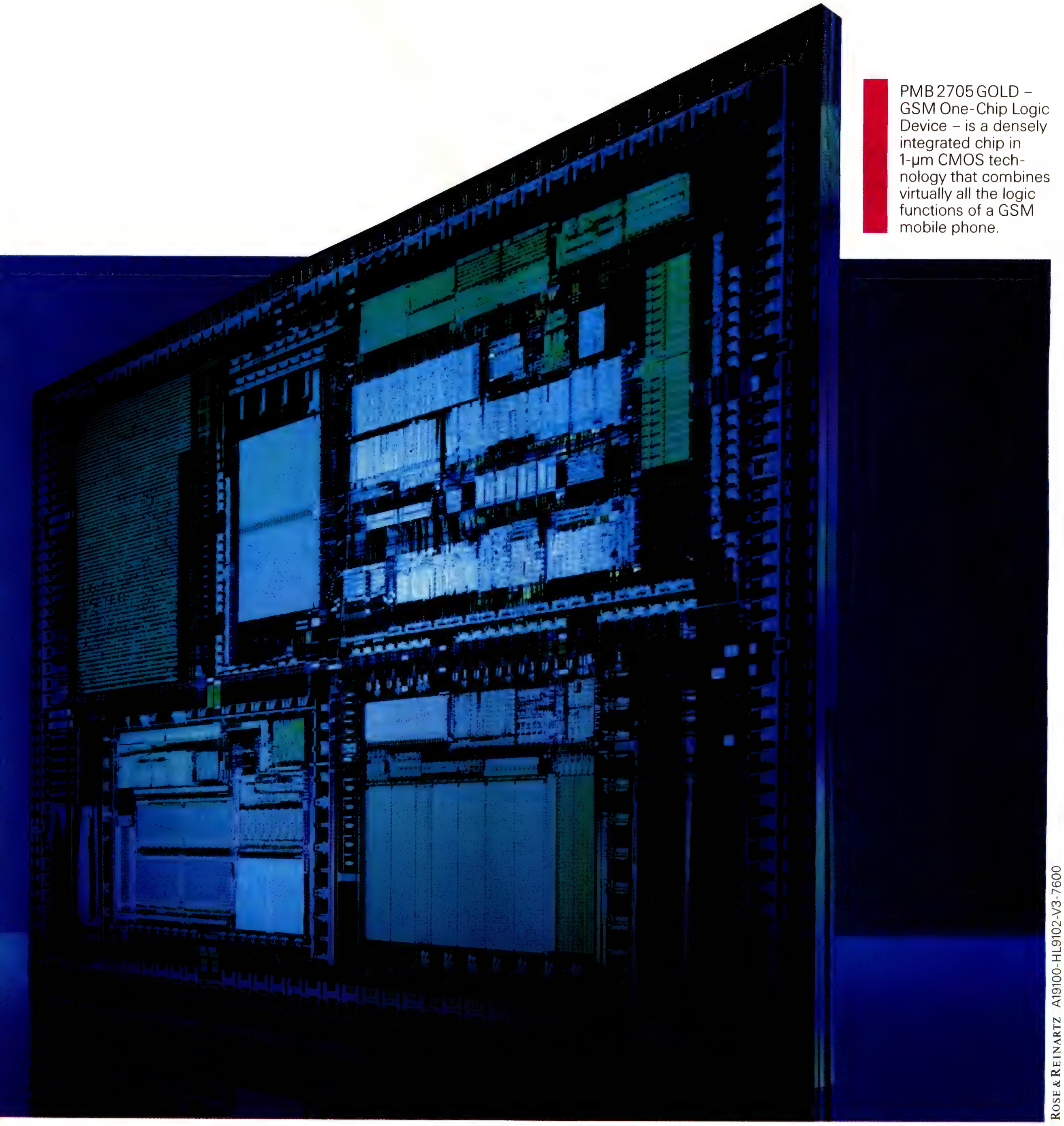PMB 2705 GOLD – GSM One-Chip Logic Device – is a densely integrated chip in 1-µm CMOS technology that combines virtually all the logic functions of a GSM mobile phone.

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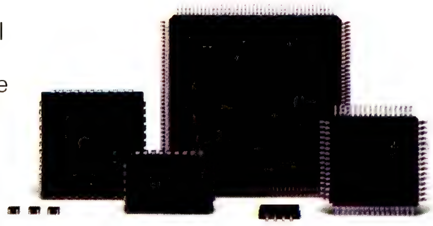

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uted computing with PCs' buying patterns, price points, and ease-of-use. This category is distinguished by advanced operating systems like Windows NT, Solaris, and NeXTStep; a typical price band of between $4000-12,000; high-performance platforms such as Intel's Pentium and follow-on processors; RISC processor families such as Sparc, MIPS, PowerPC, Alpha, and PA-RISC; and an emphasis on the growing commercial market space that workstation vendors have failed to penetrate due to lack of applications and the right price.

At the heart of any PC, personal workstation, or engineering workstation is the CPU. Most current systems employ 32-bit microprocessors—the 80386, 80486, MC680x0, etc. However, the transition is already in motion as 64-bit microprocessors emerge from research labs. Lessons learned from the large computers on superscalar and superpipelined architectures are being applied to the processor chips, and that's pushing CPUs up to 100 to 200 MIPS. And still higher throughput chips are now on the drawing board *(see "Microprocessor Performance Onslaught Pushes On," p. 85)*.

The latest CPU releases, such as the Alpha AXP processor from Digital Equipment Corp., employs a 128-bit-wide data bus to move 64-bit words into the chip two at a time. Consequently, the on-chip cache lines can be reloaded quickly, keeping the CPU as active as possible. When operating at an internal clock speed of 166 MHz, the CPU delivers a throughput well over 100 SPECint92 and close to 200 SPECfp92. Even newer versions of the Alpha (the 21064A) run at clock speeds of 275 MHz and deliver close to double the just-described throughput, providing users with the highest performance of any commercial CPU.

Many other CPUs are moving to 64 bits as well. The MIPS Technologies Inc. Division of Silicon Graphics and its partners all released versions of the R4000 processor, which has a full-64-bit internal architecture. Sun Microsystems, along with Texas Instruments and Intergraph, announced plans to release full 64-bit implementations of the Sparc architecture in 1994. HAL Computer Systems has been working on a 64-bit Sparc-based implementation of its own, too, and also expects to release a system in 1994.

Dual 32-bit arithmetic and logic units are the current, intermediate answer to the 64-bit performance attained by both Texas Instruments in its SuperSparc processor and Intel in its Pentium, top-of-the-line x86-compatible processor. By adding dual ALUs and a floating-point processor, multiple instruction streams can execute concurrently, allowing the CPU to start more than one instruction per cycle. Motorola's forthcoming 68060, and systems from Nexgen will also employ a similar superscalar approach.

No personal workstations were shipped in 1992. Traditional workstation vendors strategized on how to penetrate the PC market, increase volumes, and go after different application areas. Today, a few vendors offer products that will be used to position their respective companies in the move down into the personal workstation space. Two examples of these are Sun Microsystems' SparcClassic and Silicon Graphics' Indy.

Introduced about one year ago, the SparcClassic created a new market-entry point—an entry-level color workstation based on a 50-MHz version of Texas Instrument's microSPARC chip. The system has performance of 26.4 SPECint92 and 21.0 SPECfp92, not much faster than today's PCs *(see Table 2 for product specifications)*. However, what the system does is break the $5000 price barrier ($4,295 to be specific) for a disk-full, color workstation.

Such a low-end price point raised an obvious question: Would workstations roll over the desktop in a big wave, potentially replacing PCs? The consensus says no. Yet future generations of this product could compete very effectively in the personal-workstation market. Remember, this system comes with relatively high-performance graphics, SCSI-based disk storage, a multitasking operating system, and networking directly integrated as part of the base system. These add-ons to a typical PC would push the PC price near, if not more than, the SparcClassic.

While exciting, the low-end announcement from Sun wasn't a technological breakthrough—it followed from the computer industry's ongoing microprocessor and packaging trends. Despite the price point similarities, this low-end workstation didn't effectively compete against

TABLE 1: DEFINING THE MERGER BETWEEN PCs AND WORKSTATIONS: WHAT IS A PERSONAL WORKSTATION?

	Power Desktop		
	Traditional Workstation	**Personal Workstation**	**Traditional PC/Mac**
Processors (examples)	Sparc PA-RISC Alpha Power MIPS Rx000 Clipper MC680x0 VAX	Intel Pentium PowerPC Alpha MIPS R4x00	Intel 286 Intel 386 Intel 486 MC680x0 Intel Pentium
OSs (examples)	ADVANCED (i.e. AOS*) Unix VMS	ADVANCED (i.e. AOS*) Windows NT Solaris NeXTStep UnixWare	DOS Mac System 7.0 Windows 3.1 OS/2 SCO Unix
Typical Price Band	**$12-15K**	**$4-10K**	**< $3K**
Product examples	Sparcstation Alpha AXP DECstation HP Series 700 Intergraph Silicon Graphics IBM RS/6000	Pentium/NT Alpha PC All desktop NT systems: (Acer, Intergraph, DEC...) Apple PowerPC with AOS Pentium with AOS Unix IBM PowerPC	Apple Macintosh Gateway Compaq Dell Apple PowerPC with Mac OS HP Vectra IBM PS/2

Source: International Data Corporation, 1993 *AOS = advanced operating system

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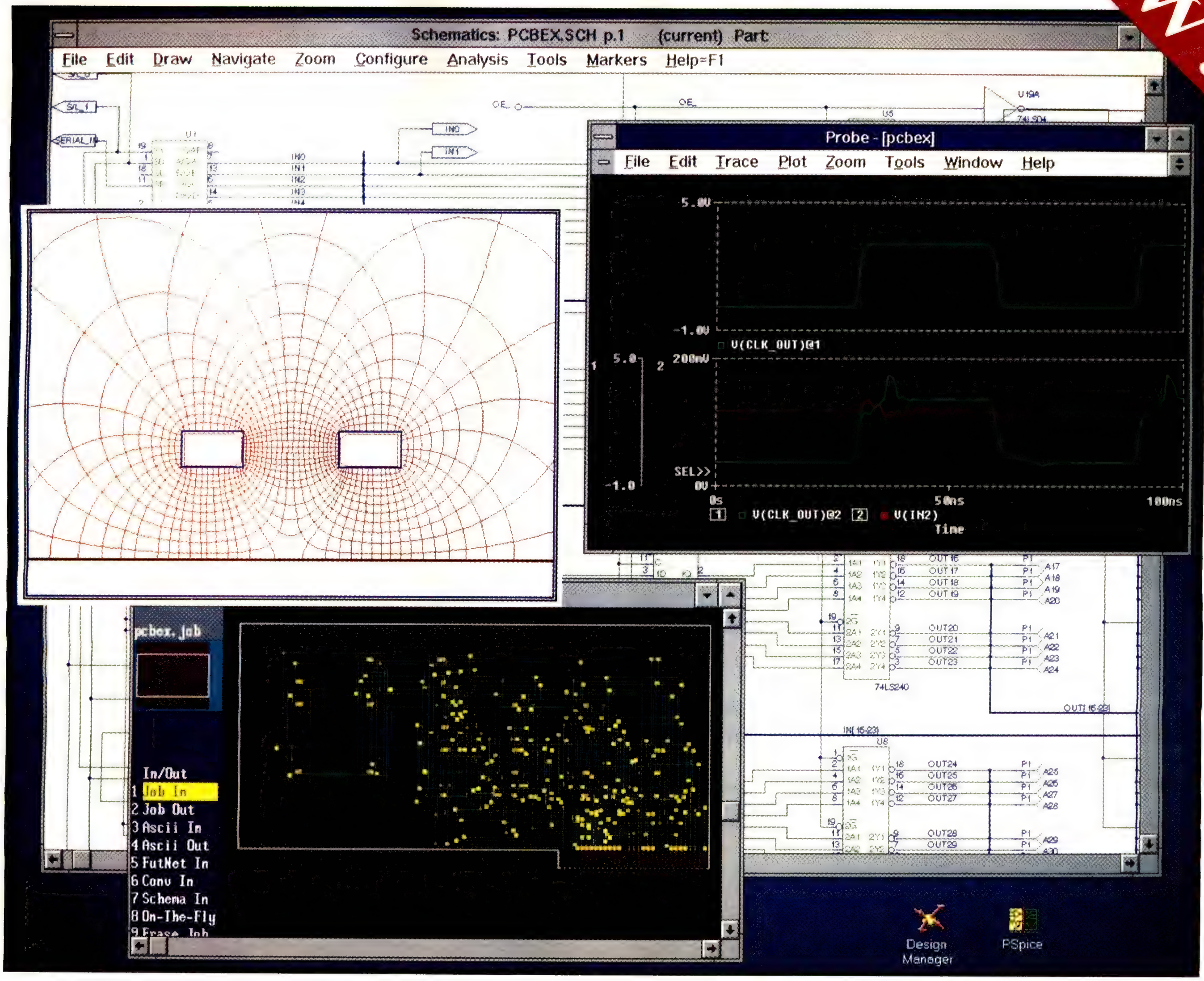

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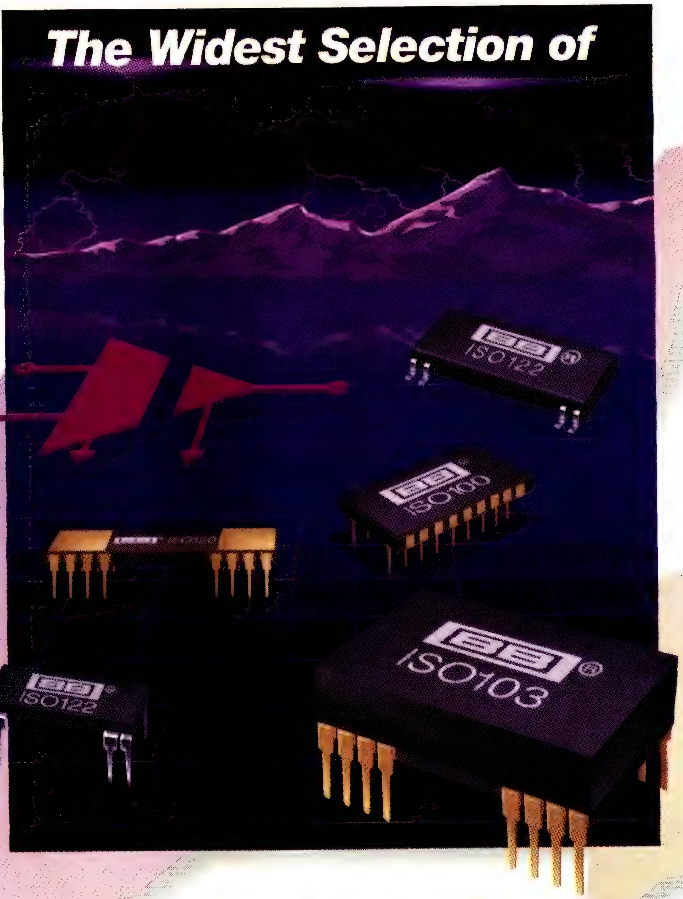

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PCs for several reasons:

- Price. The price point was still too high. The volume price point for PCs is around $2500. The $5000 price point puts workstations in the high-end PC space, which represents the minority of unit shipments each year worldwide.
- Applications software. The top PC and Macintosh packages ship multiple millions of licenses each year; the top workstation software packages annually ship several thousand licenses, at best. Many key PC personal productivity applications still aren't ported and available on Unix or other non-DOS operating systems.
- Operating environment. DOS, Windows, and Macintosh represent the desktop environments of choice on the desktop, not Unix. The Unix operating system ships on fewer than 3% of all desktops worldwide. Windows NT is expected to own the majority of the personal-workstation market and Sun today doesn't support it on the SparcClassic.
- Distribution channels. The highest volume PC vendors won't sell direct, except to the federal government and its agencies. Yet direct sales still represent nearly one-half of the total workstation business. The cost of direct sales will cripple any efforts by Sun and others to lower the price and keep up with the intense price wars of the PC market.

Although some feel the SparcClassic falls short as a replacement to PCs, Sun doesn't even try to position this type of system as a PC replacement. Rather, Sun views the system as a client in an enterprise, client-server environment. Future generations of this product will compete as personal workstations and Sun will continue to drop prices to create even more competitive client-server opportunities.

This past July, Silicon Graphics released the Indy personal workstation—a product the company expects to use to position itself in the emerging personal-workstation segment. At the announcement, Ed McCracken, president of SGI, stated that SGI wants to combine ease-of-use from the Macintosh market, volume from the PC market, and power from the workstation market. The Indy is the first SGI product to try to merge these three distinct needs.

The base Indy system starts as an under-$5000 package with 3D graphics, color video camera, multimedia-capable software, and much more. The CPU is housed in a compact pizza-box design that holds plenty of memory (16 Mbytes standard, 256 Mbytes maximum), disk (2 Gbytes maximum) and graphics expansion. In addition, it makes it possible to upgrade with future processor daughtercards. Initial system releases will come with either the R4000PC at 100 MHz performing 34 SPECint92 and 35 SPECfp92, or the R4000SC at 100 MHz delivering 58.5 SPECint92 and 61 SPECfp92. Future upgrades to the R4400 and still other processors will be available throughout 1994.

Basic graphics that 2D and 3D users require is included, such as 8- or 24-bit plane configurations, and color monitors that are either 15 in. and 1024 by 768 pixels, or 16 and 19 in. with 1280 by 1024 pixels. All configurations of the Indy come standard with audio and video I/O channels as well as Ethernet, SCSI, and ISDN interfaces. A specially developed color video camera (IndyCam), which allows immediate video capture/video conferencing, and multimedia development is included as part of the basic system. With the R4000PC processor, Indy graphics performs at 1.2-M Xlines/s, 500-k 2D vectors/s, 400-k 3D vectors/s, and 26-k triangle meshes/s (Tmeshes/s). With the R4000SC, graphics performance increases to 1.4-M Xlines/s, 600-k 2D vectors/s, 480-k 3D vectors/s, and 40-k Tmeshes/s.

User-friendly software, called Indigo Magic, is included with all Indy systems. The software includes new features that gives the user the ability to:

- Extend the desktop icons to represent files, networked computers, peripherals and even people.
- Customize desks, which allows the user to build multiple desktop environments, organized by task and customized to the user's specific work style.

TABLE 2: COMPETITIVE OFFERINGS FROM SUN AND SILICON GRAPHICS

Feature/ Performance	Sun SparcClassic	SGI Indy
Announcement	11/10/92	7/12/93
CPU	TI microSPARC	MIPS R4000 PC or SC
No. of CPUs	1	1
Clock rate (MHz)	50	100
Memory (Mbytes)	16-96	16-256
Internal Disk	207-1050 Mbytes	Diskless, 2 Gbytes
Screen size	15-in. color	15 and 16 in.
Resolution (pixels)	1024 by 768	1024 by 768 1280 by 1024
Color graphics	8 planes	8 and 24
ISDN	No	Standard
No. of slots	2 SBus	2 GIO bus
Audio	8-bit	Standard
Video-in	No	Standard
Video-in/out	No	Optional
HW Warranty	1-year	1-year
SPECint92	26.4	34.0 / 58.5
SPECfp92	21.0	35.0/61.0
First shipments	Dec. 92	Oct. 93
List price	$4295	$4995
Entry price configuration	16-Mbyte memory 207-Mbyte disk 15-in..color 8-bit color 8-bit audio Choice of Solaris 1-yr. warranty	16 Mbytes No disk 15-in. color 8-bit planes IndyCam IRIX 5.1 CD-quality audio Indigo Magic 1-yr. warranty

Source: International Data Corporation, 1993

- Execute the processes of point-and-click software installation and printing.

Dubbed the "media machine" by SGI, the Indy system is built with hardware enablers like the video camera, and software enablers such as video conferencing, media mail, and the entire media user environment. SGI bundles all of these enablers with the system, allowing the users to experiment without expensive add-ons.

Although the entry-level Indy sells for less than $5000, the average configuration purchased by users will probably run over $10,000. Future generations of Indy will most likely have lower price points.

One alternative to plummeting workstation prices is to do away with most of the workstations and replace them with X-terminals. Because many organizations are already moving to client-server organizational structures, and workgroups can considerably lower their cost per seat, many companies view the X-windows terminal as a very viable option. Terminal costs tend to be in the $1500 to sub-$3000 range, thus they're about half the price of a low-end personal workstation.

Both DEC and Hewlett-Packard, for instance, suggest that a small department should start off with one high-performance CPU and three or so X-terminals. Such a combination, for many applications, effectively gives the user the apparent performance of multiple workstations. The X-terminal approach can also be more cost-effective than multiple independent workstations plus it simplifies the software management—only one copy of the software need be installed and maintained. As a result, updates as well as both version and security control are simplified.

The limiting factors for such a system, though, show up when the interconnecting network saturates with traffic or several tasks are computation-heavy. In such situations, the terminals aren't as responsive and start to look less and less like independent computers. Many companies offer X-terminals, with some of the leading vendors, such as DEC, HP, IBM, Sun, and Tektronix, offering graphics-capable color systems. Performance rates are typically given in thousands to hundreds of thousands of Xstones, but many companies feel that rating is a poor measure of a terminal's capabilities. To improve the terminal's graphics, companies are turning to RISC processors, such as Intel's 80960 and others, to handle the local graphics control and communications.

WHAT'S COMING

The traditional workstation vendors are readying themselves to do battle for dominance in the personal-workstation market. Many are expected to offer new models or follow-ons to existing products, such as the SparcClassic and Indy. For instance, due out in the next six months is a low-end workstation from Hewlett-Packard's Entry System Division. This system, expected to be based on the PA7100LC chip (a highly integrated version of the PA-RISC processor), will be priced under $4000. Such a system will fill out HP's Series 700 workstations, and give the company a foot in the door to the personal-workstation market. HP's workstations range from about $7,000 to approximately $30,000 for their top-of-the-line workstations.

DEC's recent release of the highly integrated Alpha 21066 CPU will allow designers of NT-compatible hardware to develop high-performance systems with base prices also in the $3500 to $6000 range. Similarly, IBM's efforts in conjunction with Apple Computer and Motorola are starting to bear fruit: The first system releases based on the PowerPC 601 CPU have begun to emerge. These systems, which will run all major 32-bit operating systems—AIX, workplace OS, Apple System 7, Sun's Solaris, and Taligent (with more to come)—will give users the flexibility of running their favorite software environment on the hardware, which provides users with the best of all options.

At the 1993 Comdex show held this past spring, IBM showed a demonstration system running the Macintosh OS. In addition, Apple Computer stated that next year it will offer PowerPC-based systems configured with an advanced operating system for less than $4000. And because the PowerPC will be an open platform, many other system implementations and OS offerings can be expected from a wide range of system suppliers. The broad variety of PowerPC-based offerings will initially mimic the activities taking place in the NT platform market based on the R4x00 processor family. Also an "open" standard, the NT platform strategy started off as the ACE (advanced computing environment) initiative, and now has a half-dozen or more platform developers that will eventually offer Windows NT-compatible computers. All of the suppliers seem to be targeting the personal-workstation class.

Where does the Pentium stand in all of this? Most probably it will be at the spearhead of Windows NT platforms. Although Microsoft claims Windows NT isn't for every office worker, and that it typically requires 16 Mbytes of RAM and about 40 Mbytes of disk space to operate adequately, many Pentium systems will be sold with NT. Or they will be sold as NT-ready just to capture the potential power users who expect to migrate to NT in the next 18 months. Of course, Microsoft has various DOS/Windows upgrades to satisfy the "average" user who may only have a few megabytes of memory and a lot less available disk space.

The dominance of Pentium-based systems coupled with the expected acceptance of Windows NT on the business desktop will give traditional PC vendors an edge in gaining or at least maintaining market share in the personal-workstation segment. However, there's no clear-cut winner. The PC architecture is over a decade old and thus has many bottleneck areas (graphics and data manipulation, for instance) that could limit future PC growth. Architectural enhancements, such as the peripheral-component-interconnect bus and graphics accelerators, are some examples of what can be done to extend the overall architectural life. Workstations and their lower-cost personal-workstation cousins offer a less limited architectural direction that doesn't carry the dozen or so years of design "baggage" that's associated with the ISA (PC-AT) bus architecture. ED

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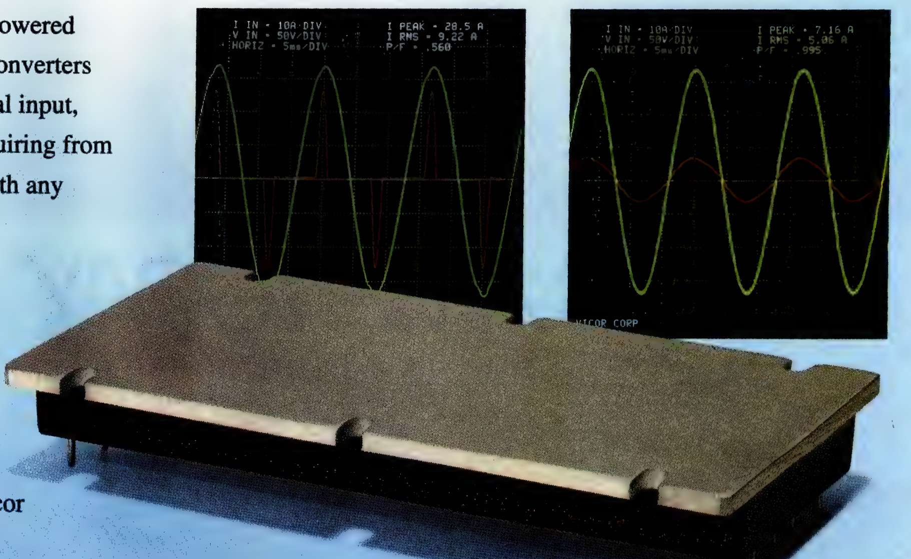

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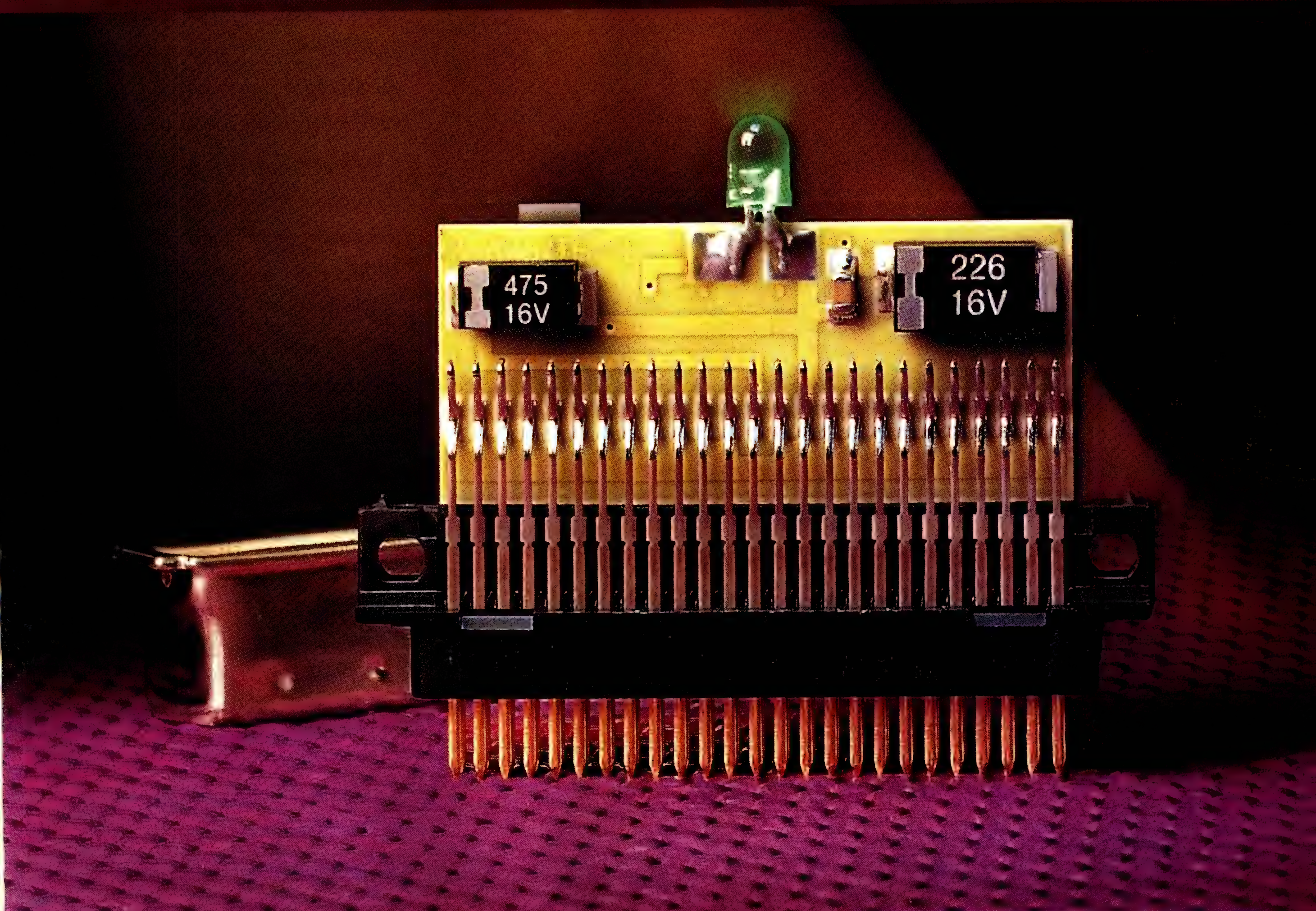

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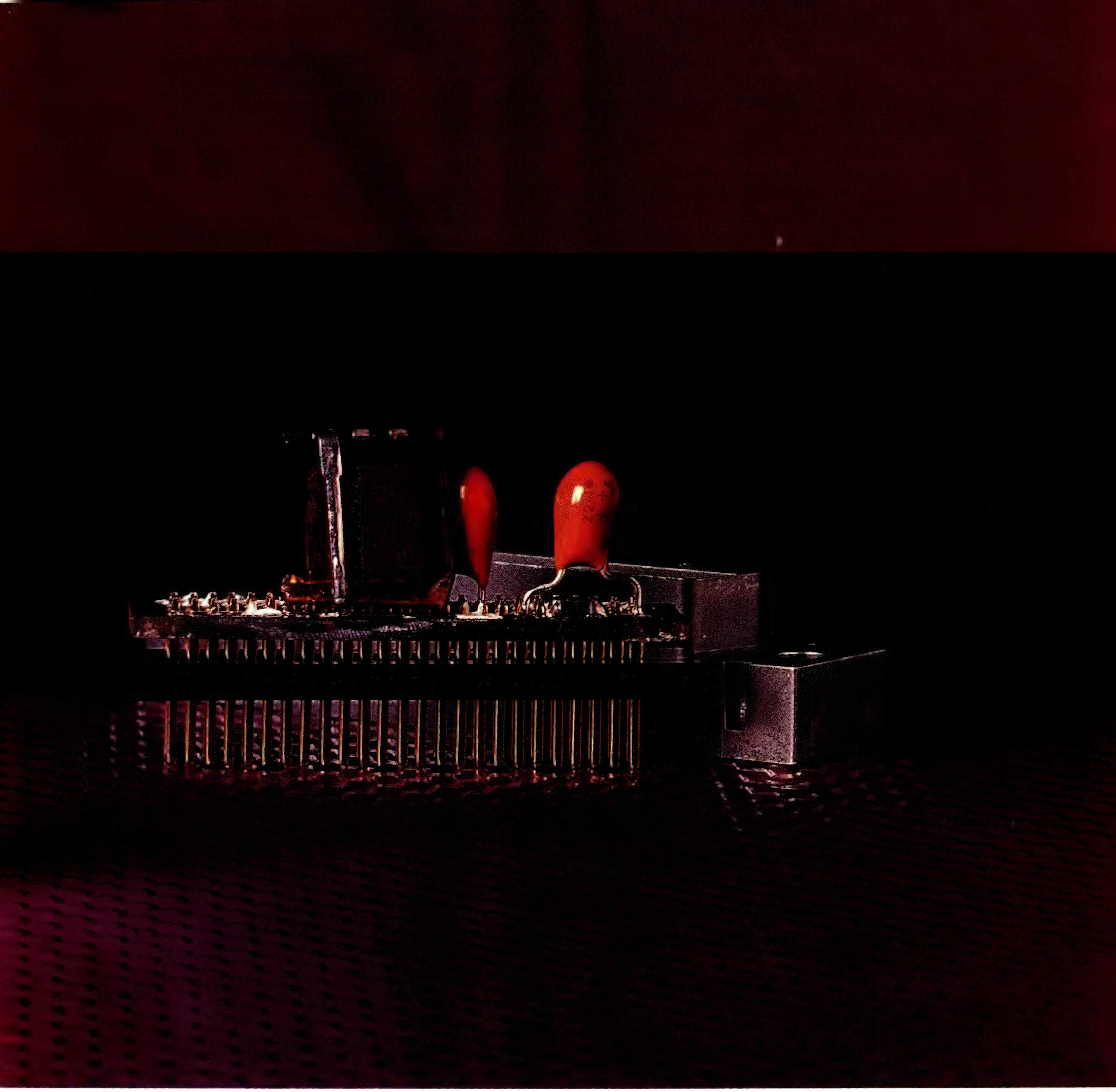

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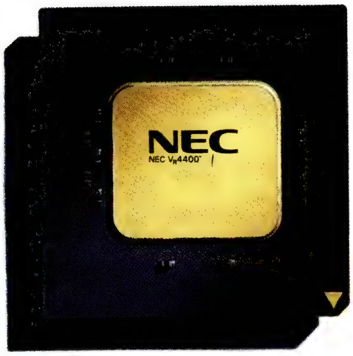

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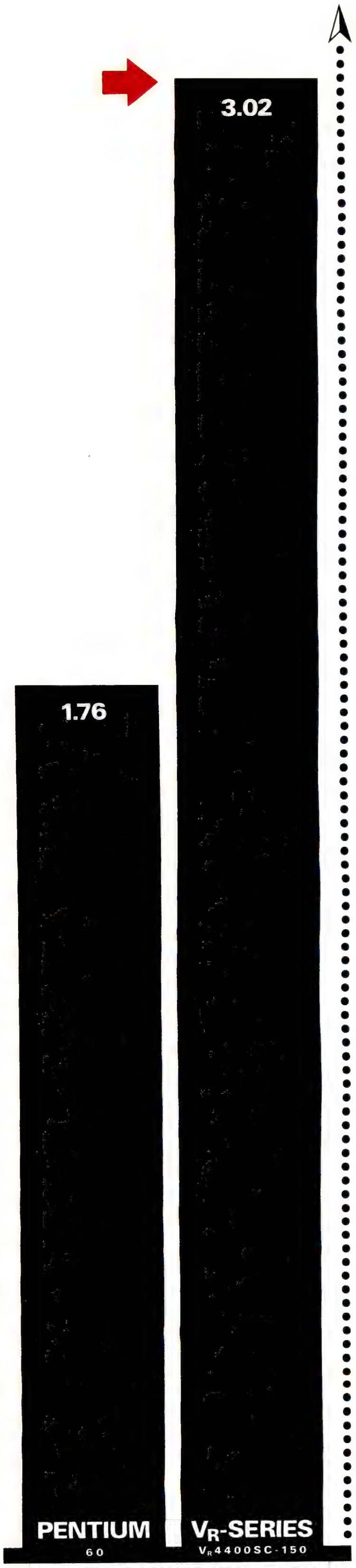

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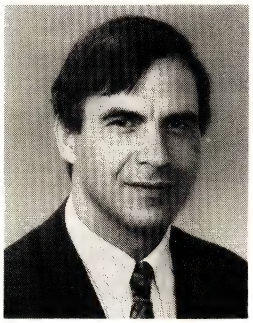
PERSONAL DIGITAL ASSISTANTS MUST HAVE MODULAR ARCHITECTURES



Gaston Bastiaens
Vice president and general manager, Personal Interactive Electronics Div., Apple Computer Inc.

THE PERSONAL DIGITAL electronics industry is only in its infancy right now. Today, handheld devices loosely referred to as personal digital assistants (PDAs) are triggering a merger of the telecommunications, computer, publishing, and consumer industries—all with a heavy emphasis on communications. But it's more than communications—it's efficient communication resulting in information that's beneficial to the user.

PDAs will go beyond collecting or distributing information by helping organize it, streamlining the operations needed to retrieve the desired information, and storing the information. Thus, to make the PDAs something other than a pocket-sized computer, they must be designed from the start with an architecture tuned for telecommunications. At Apple, we call that capability "Newton Intelligence."

For example, if a PDA receives a fax, users should not only be able to view it, but also highlight action items such as a meeting or a telephone call. The software should then be able to automatically add the meeting to a calendar, or access an address book to look up the telephone number of the person to be called.

Another aspect of the value-added intelligence is the PDA's ability to adapt to users. Not only should the software "tune" itself to better recognize written text, but it could also adjust itself to bring up specific applications automatically once the initial application is selected.

Looking closely at the PDA industry, it could potentially grow much larger than today's computer industry because it spreads into so many areas. Thus, designers must embrace an architecture that's modular to permit updates and expansions, yet with high enough performance to make practical such applications as text recognition and smart appointment books. Furthermore, the architecture must adapt itself to a multitude of communication standards.

Communications is now undergoing a revolution—wired analog links are being transformed into wireless digital telecommunications links in the form of such standards as GSM, CT2, etc. Other interfaces, including wireless networking and even infrared interfaces, are also gaining popularity. A PDA must be flexible enough to deal with any or all of these options. As a starting point, the PCMCIA interface provides a simple and easy way to add or change a system's functionality. Many companies, including Apple, have adopted the PCMCIA format as the standard for modems, RF interfaces, network adapters, and a number of other functions—at least for the first generation of personal digital assistants.

In the coming months, a pager in the PCMCIA format for use with the Newton will be unveiled. When the pager beeps, users just plug the card into a Newton, read the incoming text message, and take some action. In 1994, that capability will be expanded to two-way communications, permitting users to reply, on the spot, to the message.

By designing a highly modular system and by taking advantage of object-oriented software, designers can create a system that will never be outdated as new CPUs offer better performance and new software applications solve business needs or provide entertainment. In Apple's case, although the Newton currently uses the ARM 32-bit RISC processor as the muscle behind the operating system and applications, the software can easily be migrated to other microprocessors.

Faster CPUs comprise just one step in the progress pegged for Newton-based PDAs. Already, licensees of Newton technology are working on additional PDAs with bigger displays, different assortments of hardware and communication resources, and different mixes of embedded applications. That's the potential of the flexible, modular architecture.

For example, there's nothing to stop designers from embedding PDA-type functionality into a desktop telephone. That could give the telephone greatly expanded communication capabilities and user features, including the ability to create and send faxes, or just capture faxes and display them. Such applications, though, will depend on creating a very high interest level in the development community. To do that, the system architecture—both from a hardware and software point of view—must be open and easy for developers to tie into.

Modularity is also needed on the software side to create new applications rapidly. The object-oriented NewtonScript Language developed by Apple is just one example of what can be done to speed application development. By combining object-oriented structures and a large variety of prewritten utilities and commonly used subroutines, developers can concentrate on the unique aspects of their applications and link in the appropriate library modules. Furthermore, by working in a high-level language, the applications will easily be able to be recompiled for a different target CPU—a PowerPC chip, for example.

The combination of a flexible, modular, architecture and scripting language has already caught the imagination of software developers: In just the five weeks since the Newton was unveiled, over 1500 development systems have been sold. The design activity combined with the promise of more powerful hardware to run future applications opens up a wide range of opportunities for many PDA variants over the next few years. ED

THE COMING OF THE PERSONAL WORKSTATION?

NEW ARCHITECTURES GIVE USERS WIDER CHOICES IN A COMMON HARDWARE PLATFORM

ALTHOUGH THE hardware capabilities of personal computers and Unix workstations have overlapped for years, vendors have been unable to bring common platforms to market. That's because key hardware components were lacking in performance. However, the final pieces have fallen into place with the introduction of the peripheral-component-interconnect (PCI) bus and Windows NT operating system. Computer customers now can choose their operating environment based purely on software considerations using a common hardware platform.

William Jackson
Worldwide marketing manager, Alpha AXP PCs and low-end workstations, Digital Equipment Corp.

The merger of the Unix workstation and personal-computer market has been talked about for sometime. In 1989, International Data Corporation, Framingham, Mass., coined the phrase "Personal Workstation" to encompass those machines that had capabilities of both personal computers and Unix workstations. In the last several years, all of the major vendors have offered Unix workstations with better performance, more capability, and at lower cost than top-end personal computers. Conversely, many personal computers now have the capabilities of Unix workstations after networking, graphics, and high-performance storage-disk options were added. Nevertheless, the predicted merger of these two hardware platforms did not happen.

When looking at the factors behind the "non-merger," one finds two major differences between PC and Unix-workstation platforms. The first and most obvious difference lies in the Unix and DOS/Windows software environments—the easy-to-use Windows interface for personal computers versus the scalability and networking features of Unix systems. Until now, the Windows environment was limited to computers using Intel x86 processors, while Unix systems were typically based on much higher performance RISC microprocessors. These differences often left the Windows user with a dilemma: To get the higher performance of RISC computing or other Unix-like features, the user must trade off the familiar Windows environment. The same could be said for the Unix user: to get the ease-of-use, such features as the high performance associated with RISC processors must be eschewed.

The introduction of the Windows NT operating system by Microsoft has altered this landscape. The Windows NT operating system supports the ease of use that personal-computer and Windows users expect, but does so on newer, high-performance RISC microprocessors.

Indeed, Digital Equipment Corp.'s Alpha AXP RISC architecture was designed to take advantage of new and emerging operating systems. The Alpha AXP RISC microprocessor is the first microprocessor of any type to integrate the high-performance PCI bus right into the CPU. This approach provides a highly integrated solution for designers of desktop computers and embedded-control systems. Both the 166-MHz 21066 AXP microprocessor and the 66-MHz 21068 AXP microprocessor are highly integrated devices, containing, besides the PCI bus, a memory controller, cache memory, a programmable phase-locked-loop clock multiplier, and a graphics-accelerator circuit.

Furthermore, the availability of Windows NT and DEC OSF/1 operating systems on the Alpha AXP architecture gives customers the ability to pick the operating environment they want. At the same time, they're also accorded the flexibility to switch systems if their needs change in the future. Consequently, this eliminates one major obstacle in the merger of personal computers and workstation.

The second obstacle involves the differences between the I/O structures of these machines. Unix workstations typically demand much higher performance from their I/O systems to match those of the higher-performance RISC microprocessors. Personal-computer users, on the other hand, have come to rely on the general availability of multitudes of options for the Industry Standard Architecture (ISA) and now the Extended Industry Standard Architecture (EISA) buses. Workstations based on these buses were often impractical and unbalanced when coupled with the new modern microprocessors. However, personal-computer vendors could neither afford the additional cost for high-performance I/O nor the perceived incompatibility with the vast numbers of third-party boards.

Here, the pending introduction of PCI-based systems and options removes the final impediment to a hardware platform that will ultimately suit both personal-computer and Unix workstation users. With a throughput of up to 133 Mbytes/s, the PCI bus supplies the performance needed to balance the designs of high-performance RISC CPUs. It also provides an affordable way for personal-computer vendors to offer a mechanism that supports standard EISA or ISA bus options—truly the best of both worlds.

Differences will surely exist in packaging, bundled options, and supported options. But the merger of the personal-computer and workstation platform *is* just around the corner. In coming months, you can expect RISC-based systems featuring PCI-based I/O structures that will be usable in either Windows NT (personal-computer) or Unix operating-system environments. In fact, Digital Equipment Corp. recently showed its first PCI-based personal computers (both x86 and Alpha AXP versions) at the Comdex Convention in Las Vegas, as well as a full line of PCI-based graphics and networking options supported by Windows NT, DEC OSF/1, and OpenVMS operating systems.

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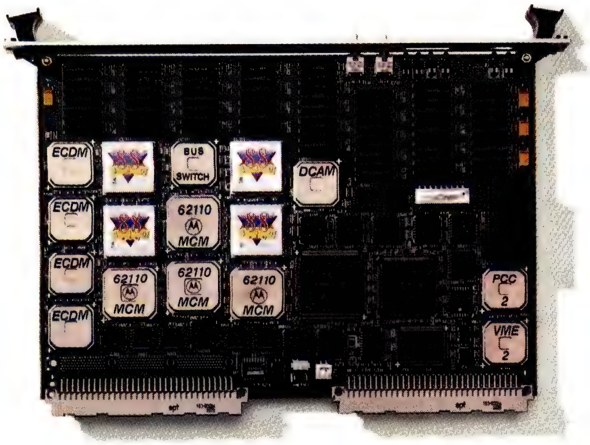

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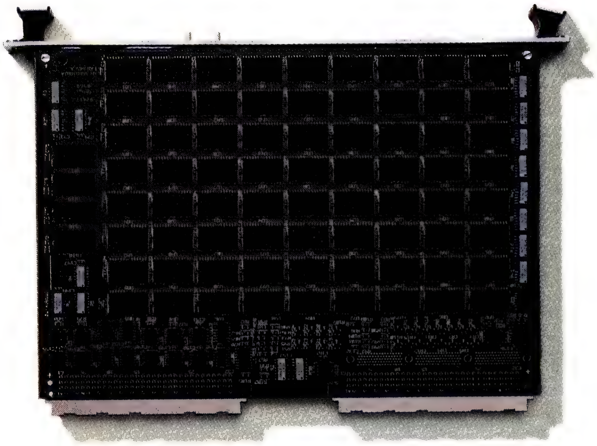

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NETWORKING VISION FOR THE 90s

USERS NEED INTELLIGENT NETWORKS FOR TRANSPARENT DISTRIBUTED COMPUTING

Randy Meals
General manager, Information Networks Division, Hewlett-Packard Co.

WHAT OUR CUSTOMERS really want and what the networking industry seeks to provide is worry-free networking. Customers essentially want to use intelligent networks that allow true transparent distributed computing. They also want their applications available at all times with the flexibility to change their environment as their business changes.

Applying the right networking scheme, end users will be able to access any application or data resource regardless of where it resides on the network. They also will be able to support all new data- and bandwidth-intensive applications, such as when engineers work together via interactive video, and support these new applications while cost-effectively integrating into existing, or legacy, environments. As the industry creates new advanced networking technologies, users should not have to start over when they adopt a new technology.

HP sees several computing industry and application trends occurring over the next decade that will spur on the creation of new networking techniques. As businesses deploy distributed applications that share large quantities of data, they create demands for much faster I/O and networking. As compute servers and clustered configurations exponentially increase in performance, and as applications are developed that take advantage of this compute performance, the network and I/O subsystem become the bottleneck. Currently, the networking industry is working to set standards and develop products like Fibre Channel, which is an interconnect technology that operates more than 100 times faster than existing networks. It allows both network and I/O traffic to travel over the same media with enough speed to keep pace with new, powerful computers.

Voice and video are being merged today with data traffic over the LAN, and now users need technologies that were originally suited for WAN environments to scale down to the desktop. In addition, transmitted voice and video require guaranteed delivery, which is forcing a change from shared media to switched data links.

ATM and Fibre Channel are two networking approaches being developed to support new application performance needs. But other areas must be addressed, such as managing the distribution of applications and resources they use. However, most end-user organizations aren't equipped staff-wise to deal with distributed resources, which typically include servers distributed throughout the enterprise. This environment can also include multiple networking protocols, such as TCP/IP, SNA (synchronous network architecture), and network operating systems like NetWare. Thus, many end-user organizations are looking to centralized Information Technology (IT) organizations to manage these distributed environments.

Obviously, solutions are needed to intelligently manage both the network and the systems on the network. Administrators and operators require tools that integrate network and system management while managing both new and existing environments—without using up available network bandwidth. HP's OpenView handles multivendor systems and multiple network protocols using the intelligent-agent concept to keep network traffic to a minimum. OpenView solutions will continue to grow to support new network topologies like ATM. In addition, management will extend to cover higher levels of middleware, such as being able to manage and control distributed computing environments like messaging and OSF's Distributed Computing Environment (DCE).

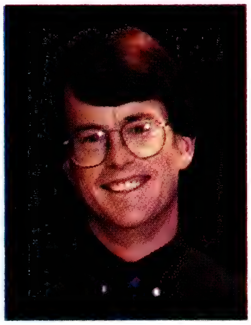
Finally, any new networking technology must take into account existing environments. As a supplier of network solutions, we can't expect users to "rip out" what they have and replace it with newer, more powerful technologies. Users need viable plans to migrate to new solutions while protecting their current investment. New technology such as HP's proposed 100 base-VG, which supplies 100 Mbits/s over unshielded twisted pair, should protect existing investment in LAN wiring, while scaling up bandwidth.

Users also will want to deploy their distributed environments over multiple vendors' hardware and operating system environments. HP sees distributed computing middleware that's hardware- and operating-system-independent as the infrastructure needed to achieve portability and interoperability. Key middleware technologies like OSF's DCE and de facto standard network operating systems like Novell NetWare will be used extensively to realize the required portability and interoperability.

HP will not only support these key middleware environments, but also add value in integrating these environments to achieve true location transparency. Global directory services and distributed file systems that provide location transparency are just two areas being exploited to achieve integration between disparate environments. Networking and network middleware will be the "glue" that makes it possible for applications across multiple computing environments to coexist and integrate. And, as distributed computing and client-server architectures proliferate, networks must become more intelligent to support better management, proactive capacity planning, and reliability. To buoy such efforts, HP recently introduced EASE, Embedded Advanced Sampling Environment, into its Ethertwist network components to support proactive resource management and capture usage trends.

POWER COMPUTING COMES TO THE DESKTOP

THE DESKTOP OF THE FUTURE WILL GIVE USERS A NEW PERSPECTIVE



Phil Hester
Vice president of systems and technology, IBM Advanced Workstations and Systems Division

THERE'S NO BETTER TIME to be a power desktop user. Technology today makes it possible to fit nearly three million transistors onto one chip. For example, IBM's RISC System/6000 POWERstation/POWERserver 250 entry desktop series, which utilizes the PowerPC 601 single-chip microprocessor, has been measured at a SPECint92 rating of 62 and a SPECfp92 rating of 72.

Compare that to the capabilities just three years ago of IBM's initial RISC System/6000 models, which had processor complexes of up to nine chips and contained seven million transistors. While the SPEC 92 benchmark suites didn't exist back then, we would estimate that our highest-performance system from that time—the 930 rack-mounted server—would have achieved SPECint92 and SPECfp92 ratings one-half to two times lower than the 250 series. Memory capacity has also more than doubled. In just three years, capabilities greater than our 1990 highest-performance rack systems have become available right at the desk, and at desktop prices.

Such a level of performance changes the way computing is perceived. At the simplest level, many of the functions that require additional hardware (3D graphics and speech recognition, for example) can now be done by the processor, saving the cost of hardware and increasing system flexibility. Clearly, this leads to new human interfaces on the desktop, such as continuous voice recognition, realistic visualization, multimedia, and even virtual reality.

Much of these capabilities are here today. IBM has announced soft 3D capability for its entire range of RISC System/6000 models. IBM also demonstrated speech recognition and compressed video playback totally implemented in software, using the PowerPC 601 processor.

Desktop-computing performance will continue to improve, doubling every 12 to 18 months, with system support technologies keeping pace. When IBM brings the POWER2 (its newest superscalar implementation is capable of 500 million operations/s) to the desktop in the near future, desktop supercomputing will become a reality.

Also critical in desktop workstation computing is the need to interoperate with PC-class systems that have prevailed over the last decade. Thousands of applications have been developed for these computers, thus filling a vital role in many desktop environments. Historically, using applications designed for different systems (DOS, Macintosh, etc.) required having separate systems that would run the applications natively. Or it meant suffering with non-optimal performance by simulating one architecture on another system, and waiting for a vendor to provide the application on the new system—less than optimal solutions.

Fortunately, software-emulation technology is evolving. IBM has demonstrated software technology that allows DOS, Windows (through Wabi), and Macintosh applications to run as efficiently on its PowerPC 601-based RISC System/6000 model as they do on high-performance native systems. Using the WinTach benchmark, which measures performance of systems running various Windows scenarios, the 250 system finished the benchmark in about half the time of a 66-MHz, 486-based PC with a local-bus-attached video adapter.

It's important to remember that the 250 is a workstation with all of the memory, I/O, and graphics subsystems designed for workstation support, thus it carries a corresponding higher price point than a PC. The intent is not for it to be viewed as the world's fastest PC, but rather to recognize that the technology allows PC-based applications to run unchanged on IBM's open-systems platforms at very acceptable performance levels.

This provides a significant step toward a common, user-friendly platform. Users will now be able to run virtually any application on a single system, or mix and match applications as a way to improve efficiency. In addition, it removes a significant burden from the application developer, enabling the industry to focus on the important things—namely, to make business more efficient.

The desktop also provides access to enterprise computing, both as a part of and a user of the more powerful enterprise servers. As communication capabilities—such as Fiber Channel and asynchronous-transfer-mode (ATM) technologies—steadily expand, desktop systems will continue to become parts of large distributed computing networks. Evolving and new software standards will help systems from many different vendors interoperate in large compute networks.

As the power of desktop systems grows, many of the applications typically executed on enterprise servers will migrate to the desktop. Applications on higher-performance systems can then begin to address more complex requirements in both scientific and commercial markets. This underscores the need for systems to adhere to industry standards and, ideally, provide complete binary compatibility across a broad product range.

Through single and multichip implementations of the PowerPC architecture, IBM will be able to build a family of products that range from "palmtops" to "teraFLOPS." Binary compatibility will be maintained across the entire product spectrum to provide a comprehensive family of solutions, regardless of performance needs. At the same time, desktop performance growth will be supported by technology sharing wherever and whenever appropriate. ED

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WHAT THE FUTURE HOLDS FOR COMPUTER BUSES

USERS CAN LOOK FORWARD TO DISTRIBUTED HIGH-SPEED I/O ARCHITECTURES

Ray Alderman
CEO, North America,
PEP Modular
Computers Inc.

WHAT WILL COMPUTER buses look like in the future? By all indications, they will conform to the same three high-level trends that have always dictated the future of electronics equipment: the boards will be smaller, the interface will be faster, and prices will be lower. Such trends have dominated I/O bus introductions over the past two years, as seen in proprietary mezzanine buses in workstations, the PCMCIA standard for portables, the VESA local bus (VL-Bus) and the Peripheral Component Interconnect (PCI). All of these busboards are smaller, faster, and cheaper than the previous generation of ISA, EISA, Sbus, Turbochannel, and Microchannel cards for the same level of performance and/or functionality.

Technically, the smaller/faster/cheaper buses being introduced are I/O buses, not system buses. This assumes that the system bus is a processor-oriented local bus on a motherboard like the PC platforms or the workstation boxes. Does this mean that future modular computers will consist of a busless single-board computer with cheap I/O expansion slots? Well, to some degree, yes.

Many applications require modularity at the system-bus (VME, Futurebus+, and so on) level, which involves such areas as telecommunications, statistical quality/process control, military weapons systems, and machine control. Cost-sensitive applications will follow the route of the desktop technologies (cheap motherboards with mezzanine I/O expansion). And single-board computers plugged into systems buses (like VME and FB+) will follow the same economic model of inexpensive I/O on the CPU card to keep costs down. Then, the CPU board can plug into a system bus with expensive, high-speed I/O interfaces like ATM, Fibre Channel, FDDI, and Sonet.

The system-bus model of the future will integrate the high-volume/low-cost desktop mezzanines with the high-performance/larger board size of system-bus modules. Overall, the system-bus CPU module will become a platform for inexpensive I/O buses, like the motherboard in a PC. Thanks to the emerging high-density packaging technology at the chip, pc-board, and connector levels, the system-bus CPU module will also shrink in size. Functionality and performance won't suffer; in fact, they will increase sharply, thanks to microprocessor geometries and processes that reduce feature sizes and heat dissipation.

Those trends also suggest that the local bus on a modular CPU card or a motherboard is a parallel bus. Will the system bus of the future be parallel? Too many recent innovations say that's not the case. Parallel buses in a 19-in. rack require higher power (> 100 mA) on many more data and address lines (> 64) to accomplish any real increases in throughput. Consequently, the outlook for the system bus seems to center on multiple very-high-speed data paths. Contrary to previous-generation computer architectures, future computers will always be assumed to be communicating with other remote devices besides slow I/O cards.

The primary trend looming on the horizon for buses is the distributed high-speed I/O model, not the centralized slow-speed I/O model of the past. Parallel buses can't keep the pace achieved by serial buses cost-effectively. Parallel buses will be relegated to parallel-bus node architectures for the serial data-mover buses. Future bus architectures will be constructed from the point of view of the data (the serial steams), not the processor (the parallel streams). The flurry of local-bus (low-cost mezzanine I/O) standards is simply the propeller-driven thinking of the present market share holders in the microprocessor and systems fields to hold their share. Serial bus protocols (like ATM) will break their parallel-bus market grip by the end of the decade.

This grip could be broken earlier as pressure mounts to solve the problems of I/O bound architectures. Here's where software success may sell hardware. As true multitasking operating systems and derived real-time kernels (such as Windows NT and Cairo) embrace larger volumes of I/O per user, thus becoming attractive in industrial settings, serial data movers will also grow more attractive. Most I/O transactions are data transfers and high-speed CPUs risk data starvation when implemented on established architectures, particularly in multiprocessor systems. The reversal of the relationship between CPU and I/O bandwidth creates new intra-crate demands on the parallel interconnect mechanism between systems resources. A serial interconnect mechanism—a true data mover—may be the savior for previous-generation architectures. Any barrier to salvation will likely be cost, not performance.

Previous-generation architectures put the CPU at the center of the computing universe and all associated interfaces were parallel-bused like the processor. Ptolemy (AD 127-151), a Greek mathematician and astronomer, defined the astronomical universe in much the same way (the earth at the center and the heavenly bodies revolving around it). Polish astronomer Nicolaus Copernicus (1473-1543) redefined the astronomical universe with *the sun* at the center. The Copernican theory of computer architecture puts the data at the center and CPU devices are satellites. Between Ptolemy and Copernicus, a number of scientific types came up with a similar idea, and spent most of their lives in prison because the reality of the universe's structure challenged prevailing religious beliefs. The same will happen in computer architectures based on financial beliefs—a different form of religion that's another story unto itself. ED

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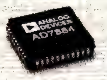

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MULTIPROCESSING TO LEAD THE WAY

MULTIPROCESSOR-BASED SYSTEMS WILL PUT LOW-COST, POWERFUL COMPUTING ON THE DESKTOP

Chuck Narad
Senior staff engineer, Sun Microsystems Computer Corp.

MULTIPROCESSING (MP), a technology usually found in high-end mainframe and costly supercomputers, will revolutionize desktop Unix-based computers. MP offers as much to desktop users as it does to large-scale computing engines and network servers, and certainly is a better option than regularly trading in an old uniprocessor system for a faster model. A dual-processor workstation may cost about 20% more than a similarly equipped single-processor system, but it can provide performance gains of 25 to 100%.

For cost-conscious designers, a modular, scalable, and shared-memory MP workstation with a multithreaded operating system will serve as the ideal future solution, with throughput being its major advantage. Its architecture lets all processors and I/O see the same memory image at all times, with caches keeping copies of recently accessed data and instructions close to the processor. Performance can be boosted simply by adding processor modules, or by upgrading to newer, faster modules. A few computer companies now offer such systems.

In networked design environments, great demands are being placed on a workstation's multitasking capabilities. Computer users have seen interactive performance degrade when compute-intensive tasks are run on even the fastest uniprocessor workstation. On an MP system, the multiple tasks are distributed among the available processors and run truly simultaneously. Shared-memory MP lets users get real, not apparent, multitasking concurrency.

A design engineer can run a schematic-capture application while simultaneously executing a circuit simulation or analysis on the same machine. In fact, it's conceivable that multiple simulations could be spun off and run simultaneously on multiple processors to test different variations of the design being created—all on the engineer's desktop MP system. It's like having a server built into the desktop.

Performance is increased by multithreading, which involves breaking a single process into separate parts that run concurrently on multiple processors. Threads are mechanisms to assign logical parallelism in an application or in the operating system. A myth is that all single-threaded applications must undergo a lengthy, difficult rewrite to benefit from MP. In reality, existing applications will likely have high throughput on an MP system, because these programs and system tasks have a pool of processors to share and contend much less frequently.

Running applications in parallel is quite a bit easier today than commonly believed, thanks to advanced multithreaded Unix kernels and a growing supply of useful tools. For instance, a leading vendor of EDA tools and Sun Microsystems joined forces on an engineering project to parallelize an advanced digital simulator for Sun Sparc multiprocessor systems, the results of which were quite successful. A new multithreading technique, in preliminary benchmark tests, boosted performance from 150 to 200% compared to its uniprocessor version. Only minor alterations to existing code were required. Consequently, development time was cut to a very short eight weeks using just one engineer.

Multithreaded kernels, such as Solaris 2.2, improve operating-system performance, enabling them to run more efficiently than standard uniprocessor systems. Because of its inherent multitasking capability, Unix naturally spawns off multiple tasks—I/O functions, E-mail, the window manager, and various administrative jobs—that can be run simultaneously on multiple processors. Scheduling is automatic, and the multithreaded kernel comes at no cost to the user.

Performance can be improved by splitting an application into separate processes that all run concurrently in an MP system, as is commonly done in transaction processing. Here, multiple users make independent inquiries or updates to a database running on an MP system, with each transaction being executed on a separate processor.

An automatic parallelizing compiler can increase Fortran application performance, where programs can be recompiled into a "micro-tasked" application. With such code, the execution of the various loops is spread across available processors at run time, and achieving this is as simple as recompiling. The compiler also provides a report on the parallelizing it has done, enabling the programmer to add directives for an even greater level of parallelism.

However, these directives don't prevent the source from being compiled with another Fortran complier for other platforms; they're simply regarded as comments and are ignored. Also, the micro-tasked binary can be run on both uniprocessor and multiprocessor machines. Fortran programs can therefore take advantage of an MP/multithreaded system with little or no programmer effort, maximizing application performance without impacting portability.

Multithreaded applications increase *single-job* performance. Many people consider this advantage as the traditional, and sometimes the only way, to realize MP benefits. Multithreaded code can significantly decrease the time it takes to execute by running tasks as multiple threads in parallel. When the multithreaded operating environment offers a user-thread library, developers can easily write MP applications, taking maximum advantage of MP desktops. POSIX thread-interface standards are currently being developed. ED

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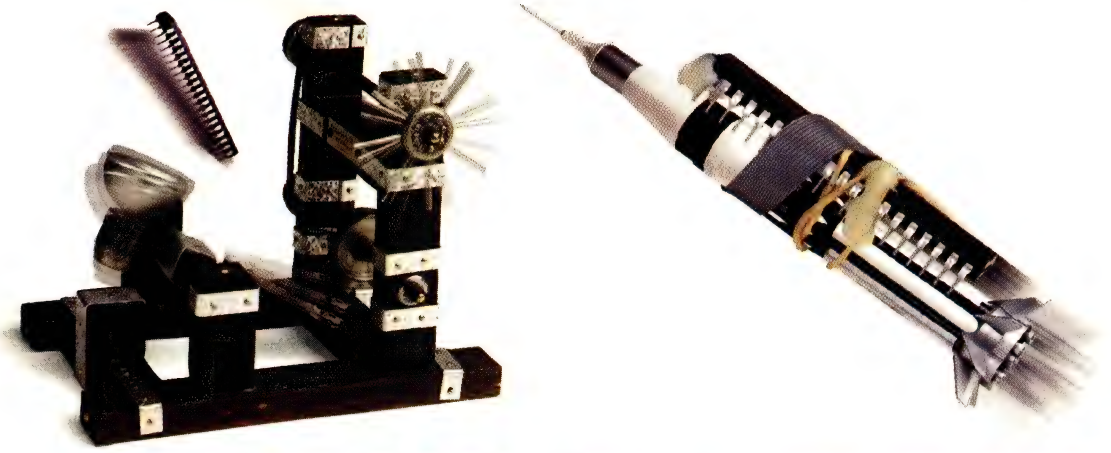

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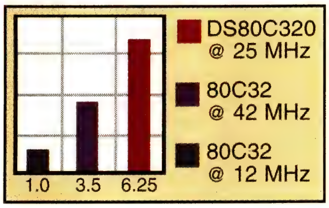

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THE TRENDS AND HOT PRODUCTS

WITH A STEADY STREAM OF IMPROVEMENTS.

BY ROBERT R. GASKIN

THE FIRST HARD-DISK DRIVE, IBM'S RAMAC 350 introduced in 1956, stored 4.4 Mbytes on 50 24-in. platters, a capacity chosen because it equaled 50,000 punched paper cards. The block/random nature of data access on the new disk drives was much faster than that of tape drives, which were already commonly used as nonvolatile storage devices. Soon after, hard-disk drives became the principal storage device for operating systems and application programs—first on mainframes and eventually on personal computers.

Optical-disk drives are now complementing their magnetic-disk-drive cousins. However, improvements in optical drives haven't kept pace with those of magnetic drives. Optical-disk proponents have been disappointed by their lack of advance in the total storage market. Another important type of storage device is the semiconductor disk card. But, other than finding their way into special applications, semiconductor disk cards haven't really challenged the magnetic-disk field due to their high cost per bit.

This article was written by industry-expert Robert R. Gaskin, president of Gaskin Research, Dover, Tenn. He has spent more than 30 years in the data storage peripherals business in such positions as engineering, product management, sales, and market research. Past associations include Sylvania, General Dynamics, Bell & Howell, Ampex, Siemens, and Dataquest (Dun & Bradstreet).

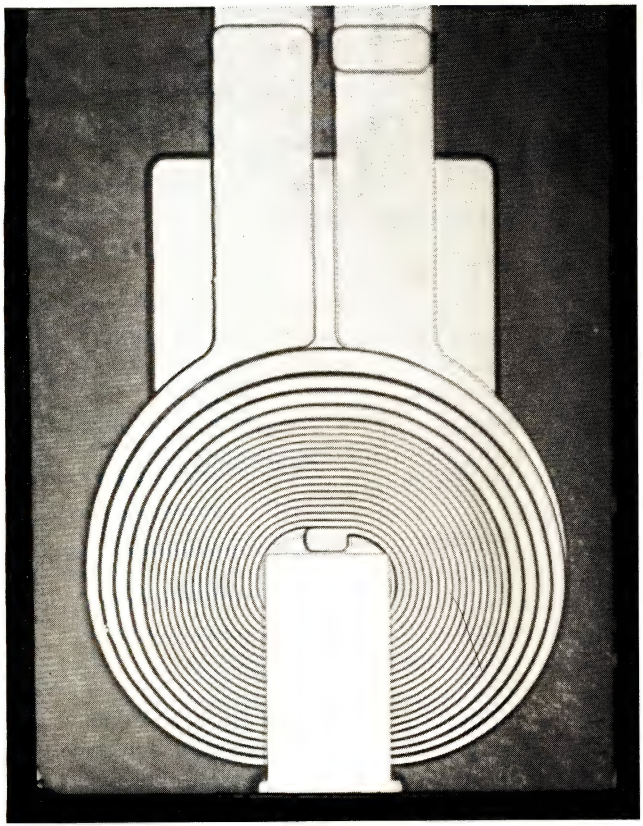
The primary figure of merit by which data storage devices are judged is areal bit density (bits/in.^{2}). Between 1957 and 1990, the rate of improvement in areal density on hard-disk drives was a rather steady compound annual growth rate of 25% per year. It did seem reasonable that after reaching approximately 100 million bits/in.^{2} in 1990, the rate of improvement might taper off. Instead of tapering off, though, there's been dramatic increases in recent years. The current rate of improvement is close to 60% per year and it appears that this pace may continue through the year 2000.

High-end disk drives in early 1993 had areal densities from 160 to 194 Mbits/in.^{2}, and by year's end some of these products will achieve 250 Mbits/in.^{2}. In fact, it's probable that a density of 1 Gbit/in.^{2} will be a production reality on advanced drives by 1997. Thus, high-end 3.5-in. drives (the most common disk size today) that store 2 Gbytes (total) today will reach 8 to 10 Gbytes in three or four years.

The accelerating pace of technical improvement is due to the confluence of improvements in several facets of disk-drive design. Disk-drive-specific components, such as recording heads and media, are enjoying continued dramatic, sometimes step function improvement. Meanwhile, silicon device improvements are enabling the use of ever-improving data-encoding schemes and error-correction techniques.

As for recording heads, the continuing need for higher areal density has resulted in the rapid shift in the ratio of thin-film heads to ferrite heads in disk drives. For many years, thin-film heads were used only in high-end captive disk drives where their original relatively high cost wasn't a factor. The need for higher areal density (and thin-film head performance) in small OEM disk drives became so great that several independent small companies entered the market to satisfy the need. Increased volumes brought costs down enough to make thin film a serious contender in the most common small drives.

Meanwhile, the life of ferrite heads has been extended by MIG (metal-in-gap) versions, but their end is imminent. The MIG heads overlap thin-film head areal-density capabilities only at thin film's low end. In addition to lacking thin-film capability on areal density, MIG heads run



1. The Censtor Flexhead thin-film monopole head is designed for contact recording in future disk drives, perhaps with perpendicular recording techniques.

into problems with self-resonant frequency. The resonant frequency of the MIG head is inherently lower than that of a thin-film head. This interferes with attempts to raise data-transfer rates on hard-disk drives. Raising data-transfer rates and reducing latency by increasing spindle speed is another strong trend in disk-drive design, and MIG heads limit how high this transfer rate can be raised.

This year, for the first time, thin-film heads represent more than 50% of the market. The ratio of thin-film heads over ferrite heads (mono and composite) is expected to increase annually until virtually all heads in production are of the thin-film variety by the 1996-1997 time frame. Until very recently, hard-disk-drive heads (ferrite, composite, thin-film) have been of the inductive type. That is, they incorporate an inductive transducer that serves both read and write functions.

Now, led by IBM, magneto-resistive (MR) heads have appeared on high-end models. These thin-film heads contain two transducers, an inductive transducer and a magneto-resistive element. The inductive transducer is used for writing, and a magneto-resistive element is used for reading. MR elements aren't sensitive to the rate of flux change like inductive transducers. Consequently, MR transducers possess an output that's independent of the velocity of the bit cells underneath the head, and they provide superior signal output from very small diameter disks. Also, the two-transducer design of the MR head allows the both the write and read track widths to be optimized. This permits the use of a write-wide, read-narrow scheme that improves data error rates caused by offsets arising from thermal and mechanical conditions.

The cost of an MR thin-film head is higher than that of an inductive-only thin-film head, but the gap is expected to tighten as volume increases. MR thin-film heads potentially can offer areal densities that are much higher than inductive thin-film heads. And the drive cost per megabyte may be lower with MR heads despite the higher component cost. MR heads are expected to comprise an increasing percentage of the total number of read/write heads used, although not entirely supplanting inductive read/write heads through the year 2000.

The push for ever-higher areal densities has resulted in a constant lowering of recording-head flying height to reduce head/media separation signal losses. The 9-μin. glide height (glide height is the test height) from 1984 has steadily diminished to the 2 μin. in today's advanced products. As flying heights were reduced, it was necessary to redesign the slider (the flying container for the transducer) to improve aerodynamic stability. Head suspensions also had to be redesigned to improve stiffness in spite of vastly reduced head loading forces.

During the next three years, drive vendors plan to drop to a 1-μin. flying height. Basically, this constitutes contact recording, and it raises new questions, particularly about wear. Thin-film heads have one critical dimension called throat height. If this dimension changes due to material wear, the head's operating characteristics change, creating a very undesirable situation.

One possible alternative is a radically different type of thin-film head designed by Censtor Corp., San Jose, Calif. The product, which has been in development for over ten years, is a so-called "monopole" design, and it doesn't have a "throat" to suffer the adverse effects of wear *(Fig. 1)*. The head is designed for contact recording and is currently undergoing extensive wear testing. Its greatest potential lies with perpendicular recording techniques, considering its small footprint and light loading force. There are some drawbacks, though, such as a high degree of sensitivity to stray magnetic fields.

No matter what type of slider is used for contact recording, areal-density improvements can no longer be made by reducing head-to-media separation. After contact recording on rigid media technology is mastered, improvements must come from other areas.

Reduced disk-drive size has put pressure on head designers to shrink the physical size of the slider. The original head used in the IBM 3350 drives, called a mini size, is used as the 100% reference mark for subsequent size standards. Today, most heads are "micro" size, which is 70% of the "mini" size.

There are substantial shipments of "nano" (50%) sliders, and a standard exists for "pico" 35% units. By 1996, the "nano" size will most likely dominate, and there will be increased use of "pico" sliders or possibly the small footprint

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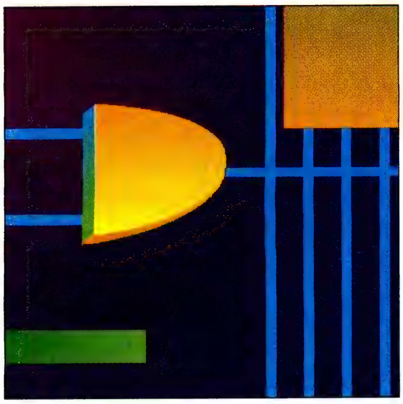

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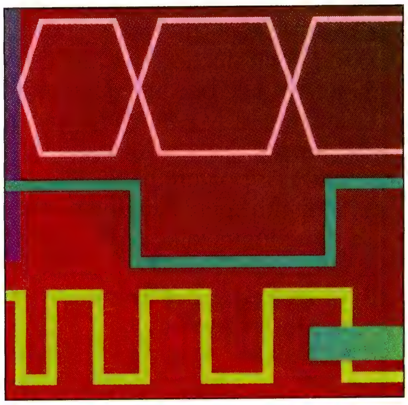

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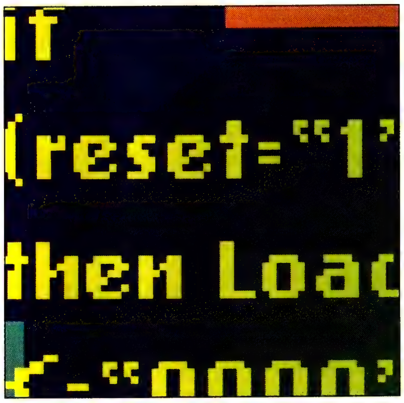

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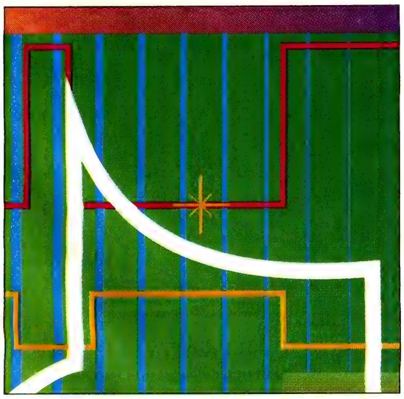

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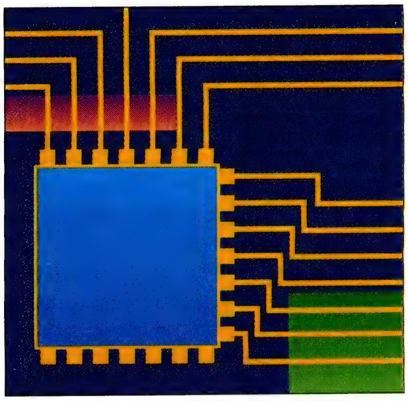

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MEDIA: STEADY IMPROVEMENTS

Magnetic disk media lies at the heart of the recording technology, and has undergone extensive changes in the quest for higher areal densities. And changes in size, magnetic coating, and substrates are expected to continue briskly into the future.

In 1956, the original IBM disks were 24 in. in diameter. The company switched to a 14-in. diameter in 1963, which was the de facto standard for over 20 years. Then, in 1979, IBM announced an 8-in. product called Piccolo, but the 8-in. diameter never achieved a strong hold in the industry. Eventually in the early 1980s, Shugart Associates introduced 5.25-in. hard drives, triggering a boom in small-diameter drives.

The 5.25-in. product toppled the 14-in. disk from dominance in numbers. But since then, the 3.5-in. diameter has taken over first place with about 70% of the small-diameter market. The industry is using substantial amounts of 2.5-in. product, and both 1.8-in. and 1.3-in. product have appeared in production disk drives. Over time, these tiny diameters should become quite popular.

Until the early 1980s, virtually all rigid disks were coated with gamma ferric-oxide particles in various binders, such as epoxy or polyurethane. The oxide coating, which was applied with spray-painting methods, eventually gave way to a thin-film metallic coating used in the early days of the 5.25-in. revolution. The metallic layers consisted of cobalt alloys applied either by the use of plating or by the use of sputtering technology.

Today, all small-diameter disks are produced using thin-film metallic layers, most of it applied by sputtering. One important magnetic characteristic of these films is coercivity, which measures the ability to resist erasure once magnetized. Adjacent magnetized bit cells in the film tend to erase each other (in conventional longitudinal recording). This tendency toward "self-erasure" becomes worse as bit cells are made smaller (higher areal density).

To counteract this tendency, it's desirable to raise the coercivity of the film (while keeping it within recordable bounds). As a result, coercivity in these recording films has been repeatedly raised from about 600 oersted in the original oxide films to 1200 and 1400 oersted in present pure metallic films. A 1600-oersted product is beginning to ship, and some 1800-oersted products are expected next year. It seems probable that in a little more than three years, new alloys other than the present cobalt (perhaps platinum) will be required.

The active magnetic layer on a rigid disk is applied to a rigid substrate as a foundation. The old oxide magnetic layers were applied directly to polished aluminum alloys. Most thin-film metallic disks use a nickel-plated aluminum alloy substrate. The need to achieve ever higher areal densities has resulted in constantly decreasing flying heights, which illustrates the shortcomings of using aluminum alloys as substrates.

2. Currently in production, the Hewlett-Packard Kittyhawk II 1.3-in. hard drive can store 42.8 Mbytes.

Imperfections in these materials are limiting flying height reduction and forcing a look at alternate materials. Already, several drive manufacturers (Areal, Avatar, Hewlett-Packard, Maxtor, Toshiba) have turned to glass-based disks for their most advanced products. The leading supplier of these disks is Hoya Electronics; other suppliers include Nippon Sheet Glass and Asahi Glass.

Pure carbon substrates are another alternative in the quest for improvement. Carbon can exist in forms ranging from soft graphite to diamond, and it seems possible that the material can be tailored into a suitable substrate material. Kobe Precision is already shipping sample quantities of carbon substrates, and its ties with Komag Inc., a leading disk maker, presumably assure it of a fair analysis. In still another approach, Seagate Technology, Scotts Valley, Calif., has announced an agreement with Corning Inc. for its alternate glass-ceramic substrate material called MemCor. It seems certain that future high-end disk drives will no longer employ aluminum substrates, but the winning alternative is still uncertain.

DISK-DRIVE ARCHITECTURE

Improvements in VLSI devices have been strongly felt in hard-disk drives. The chip count for complete drive systems has dropped to as little as five chips, reducing both cost and physical size. And with the lower silicon costs, complex run-length-limited encoding schemes (RLL) as well as error-correction circuitry (ECC) can be employed practically.

Ever larger buffers built into the drives permit command queuing and data caching to improve system efficiency. Internal buffers of 256 kbytes and even 512 kbytes are common. Buffer size is likely to grow to a megabyte or more by 1997. Buffering also encourages the use of zone bit recording, or banding, which is when there's constant bit density (or nearly so) on all tracks. This technique progressively records more sectors on each track going from the innermost track near the spindle to the outermost track (which has the largest circumference). This provides the best utilization of disk space and the largest possible data storage per surface at a given bit density. Because the disk spins at a constant

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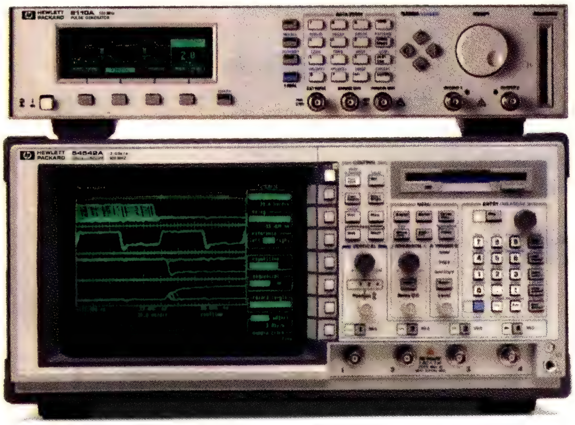

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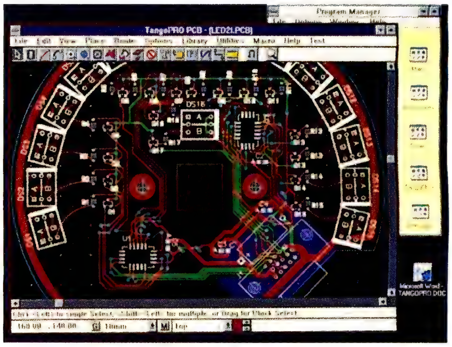

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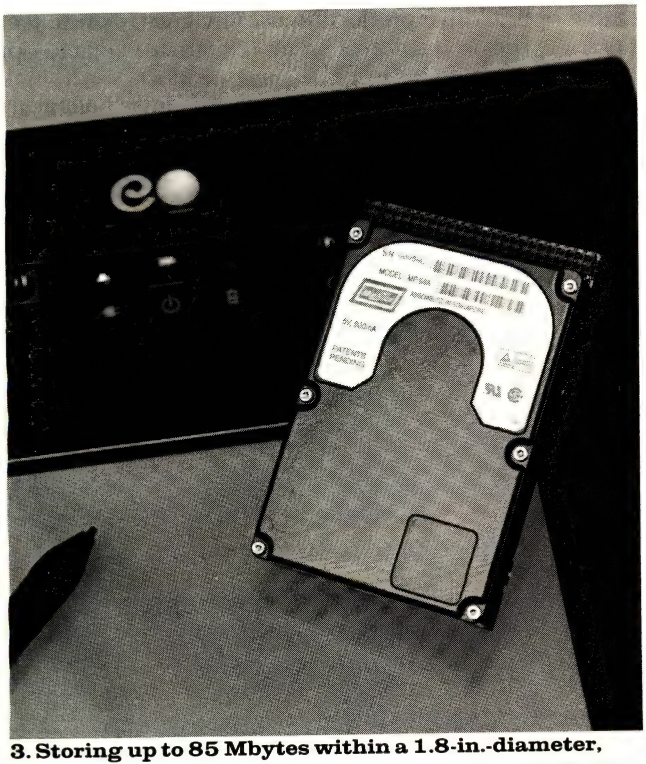
angular velocity (CAV), this technique would result in a variable data-rate output to the system if it weren't for the presence of buffering capability in the drive.

For many years, the standard disk spindle speed was 3600 rpm, which resulted in a rotational latency in data access of 8.33 ms. The 3600-rpm speed was standardized when almost all drives were 14-in. diameter. As head-actuator seek times became faster and approached 10 ms average, the rotational latency loomed ever larger as a limitation on performance.

The much smaller drives in use today lend themselves much more readily to increases in spindle speed, obviously triggering the industry to move to higher speeds. Rates of 4500 and 5400 rpm have become common, and HP has a production drive with 6400-rpm spindle speed. In addition, Seagate announced a 7200-rpm product. In fact, there's a report of lab activity looking at 10,000 rpm. It seems probable that average spindle speed will shift upward to 6400 or possibly 7200 by 1997. But it's not simply a problem of getting higher rpm, as there are reliability tradeoffs involved. Spindle-bearing wear must be considered, as should heat rise in the head-disk assembly (HDA).

To recapitulate, over the next few years, hard-disk drives will feature contact recording and will store 1 Gbyte/in.^{2}. Disk substrates will be glass or other alternate (to aluminum) materials. High-end products will have magnetic layers made from new alloys, such as platinum, rather than cobalt. Spindle speeds for the mainstream 3.5-in. products will be 7200 rpm, and 1.0-Mbyte internal buffers will be common. The 3.5-in. models will store over 10 Gbytes in 8- to 10-disk versions and over 8 Gbytes in low profile 5-disk versions. The high-end 2.5-in. drives will store over 1 Gbyte in 2-disk versions, making 2-lb notebook computers so powerful that dedicated desktop systems will not be needed by many users. And high-end PDAs and handheld computers, using 1.8-in. and 1.3-in. drives, will have more storage than the average desktop computer today.



3. Storing up to 85 Mbytes within a 1.8-in.-diameter, MiniStor Peripherals' drives are packaged in a PCMCIA standard format and can withstand operating shocks up to 200 gs.

A PLETHORA OF PRODUCTS

Hewlett-Packard, Boise, Idaho, is the first company to announce and ship a 1.3-in.-diameter hard-disk drive *(Fig. 2)*. HP's new second-generation Kittyhawk II (announced in March 1993) provides 42.8 Mbytes of formatted storage in a package that's 2 by 1.44 by 0.4 in. high (50.8 by 36.5 by 10.5 mm), and weighs 1 oz. (28.4 grams). Power required during write operations is 1.7 W; shock resistance (operating) is 150 g. The unit's 1.3-in. glass disks store 21.4 Mbytes each at an areal density of 175 Mbits/in.^{2}. Connector options include PCMCIA (Personal Computer Memory Card International Association).

MiniStor Peripherals Corp., San Jose, Calif., offers the MiniPORT 42 and MiniPORT 85, 1.8-in. drives supplying 42- or 85-Mbyte storage capacity rated for unusually high operating shock resistance *(Fig. 3)*. The drives store 42.5 Mbytes per disk at approximately 143 Mbits/in.^{2} They're packaged as a PCMCIA-standard physical format. The product comes with an AT interface, or what it says is a true PCMCIA electrical interface (MiniStor and other small drive makers probably owe PCMCIA a vote of thanks for having established these standards). Another feature of the MiniStor product line is very high shock resistance. The drives are rated at 200 gs operating shock. This certainly is an advantage in the small-handheld-computer environment targeted for the product. The company attributes the high degree of shock resistance to the following features: positive bistable actuator latch; embedded and stiffened embedded servo system; nanosliders; oversized spindle motor bearings; and sealed HDA filled with dry nitrogen.

The shock sensor technology is based on a piezoelectric film sensor used as an accelerometer. When the beginning of a physical shock is sensed, the write current is turned off. The data is automatically and transparently rewritten when the shock ceases.

Avatar Systems Corp., Milpitas, Calif., is a new producer of 2.5-in. removable hard-disk drives. The removable cartridge now stores 85.4 Mbytes on a single 2.5-in. glass disk, but higher capacities are anticipated. The glass disk, supplied by Hoya Electronics, is only 25 mils thick and has 1600-oersted coercivity.

Avatar paid close attention to the need for keeping the interior of the cartridge clean. A double filtering system is included, as well as a purge cycle on startup. The disk spins at more than the normal 3600 rpm during the purge cycle and then is slowed down for normal operation. One of Avatar's models, the Magnum ASR-80M, is bundled in the same case with a 3.5-in., 1.44-Mbyte floppy-disk drive. The

4. The highest storage density in a 2.5-in.-diameter drive is found in Areal's A260: 260.1 Mbytes, on two glass disks.

whole package is only 25.4 mm (1.0 in.) high. This provides a powerful removable storage package for just about any desktop system.

Areal Technology's (San Jose, Calif.) A260 2.5-in. disk drive stores 260.1 Mbytes on two glass disks in a compact low-power package *(Fig. 4)*. The 130 Mbytes per 2.5-in. disk capacity is at the top of the class for production drives. The drive uses standard inductive thin-film heads and can presumably advance still further with MR heads in the future. Spindle speed is a relatively slow 2981 rpm. The drive is extremely compact at 69.9 by 87.6 by 15.0 mm high. The weight is 123.2 gm (4.4 oz.), and power requirement is a low 1.65 W.

The CP-2254 2.5-in. hard-disk drive developed by Conner Peripherals, San Jose, Calif., stores 252.7 Mbytes on 3 disks, or about 84 Mbytes/disk *(Fig. 5)*. The CP-2254 excels in quickness: The average seek time (read/write) is only 12 ms. The spindle rotation speed is 4500 rpm, and data-transfer rate to/from buffer is 8.0 Mbytes/s. The power requirement in the read/write mode is only 1.4 W.

The DSP3210 from Digital Equipment Corp., Boxborough, Mass., is a 3.5-in. drive that stores 2.1 Gbytes on 8 disks, with an areal density of 194 Mbits/in.^{2} and 263 Mbytes per disk capacity. It comes in a 1.6-in. high half-height package. Spindle speed is 5400 rpm and average seek time is less than 10 ms, for an average access-to-data time of 15.6 ms. The cache buffer is a large 1024 kbytes. Media transfer rates are as high as 5.5 Mbytes/s and the host transfer rate reaches 20 Mbytes/s using wide SCSI II. A companion product, the DSP3133L, stores 1.3 Gbytes in a 1.0-in. high form factor, using only five disks. This product line is designed and manufactured for the OEM market, a somewhat new role for DEC.

Hewlett-Packard's HP C2490A is another high-end 3.5-in. product with 2.1-Gbyte capacity. HP employs 10 disks to achieve this capacity, but it spins them at 6400 rpm for an average latency of only 4.69 ms. Other features are an average seek time of 8.9 ms and track-to-track seek time of 2.5 ms.

Available from Seagate Technology is the ST3655N disk drive, which heads up a family of 3.5-in. drives in the low-profile 1.0-in.-high form factor. The three-disk 545-Mbyte drive spins at 4500 rpm and features an average seek time of just 12 ms.

Western Digital, Irvine, Calif., offers the in-production Caviar AC2420, which stores 425.3 Mbytes on only two 3.5-in. disks. The 212-Mbyte-per-disk design is one of the more advanced products available. Average seek time is under 13 ms, but spindle speed is a bit slow at 3314 rpm.

Announcements of two-disk, 3.5-in. drives storing over 500 Mbytes came from Alps, Hitachi, and others over the past year. While these drives aren't yet in production, it's apparent that 250+ Mbytes per disk will soon be the norm.

OPTICAL DISK DRIVES

The first optical disk drives for computer use began shipping in 1983. These were 12-in. WORM (write once, read many times) drives that stored about 1 Gbyte per side on each removable disk. The 5.25-in. diameter versions of the same technology, which had capacities of around 200 Mbytes per side, began to ship in 1985. Then, in 1988, Sony, Canon, Maxoptix, and Ricoh started shipping 5.25-in., 650-Mbyte-per-side rewritable optical cartridge drives, based on magneto-optical principles.

Three years later, Panasonic, Tokyo, Japan, began shipping 5.25-in., 1-Gbyte-per-side drives using phase-change technology, which features direct overwrite (up to a limited number of reversals). With this one exception, all rewritable optical-drive production uses magneto-optical technology. The production of 3.5-in. 128-Mbyte magneto-optical drives also began in 1991. These products use a single-sided ISO standard cartridge to keep drive height and cartridge thickness to a minimum. The best of these products are only 1.0 in. high and their depth is held to 146 mm. The cartridge has the potential to be very low cost and have at least 256-Mbyte capacity. The ISO standards provide for

5. The CP-2254, Filepro Notebook 250 2.5-in. drive, developed by Conner Peripherals, stores 252.7 Mbytes on three disks, or about 84 Mbytes/disk.

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Gain Error	**±1LSB max**	±10LSB max	±8LSB max	±8LSB max
Offset Error	**±1.25LSB max**	±8LSB max	±3LSB max	±5LSB max
Integral Non-Linearity	**±1LSB max**	±2LSB max	±1LSB max	±1.5LSB max
Signal-to-Noise Ratio (f_{in} = 100KHz)	**69.5dB min**	69dB min*	68dB min	68dB min

*SINAD, no SNR spec available.
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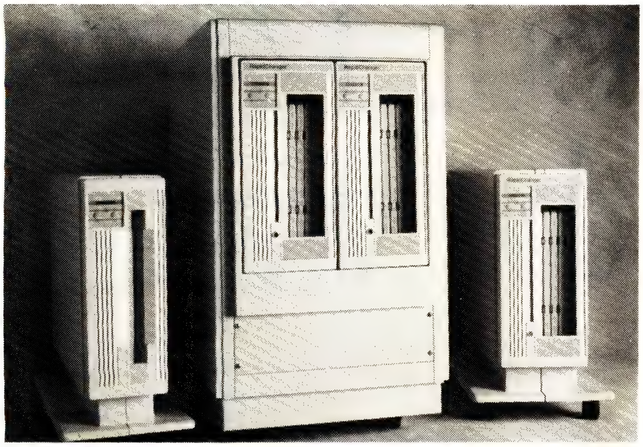

6. The Philips LMS 4100 Series family of 12-in. WORM drives features fast access to data with heads on both sides of the disk.

a read-only area on the disk, or for an entirely ROM disk. The partial O-ROM disk would seem to be a golden opportunity to distribute software and data together on the same disk, but that has yet to be done.

The principal performance advantage of optical-disk drives over magnetic-disk drives is their ability to provide a track density an order of magnitude higher than magnetic drives, thus enabling them to store much more data per disk. The principle disadvantage of optical-disk drives is a data access time that's several times slower than magnetic-disk drives. The access-time problem is due to the thermal nature of the recording process, the physical inertia of the optics, distortion on disk media spun at high speeds, and (in MO drives) the lack of ability to overwrite old data in one pass of the disk over the heads. Also, optical disk drives have proven to be much more costly than magnetic disk drives, although their removable nature can offset this in some applications.

Technology extensions on optical disk drives have developed much more slowly than with their magnetic counterparts. Given the ten years that 12-in. optical WORM drives have been in production, it would seem that disk capacity should have grown to about 30 Gbytes. Leading 12-in. products, such as the Philips LMS 4100 series, are currently at 5.6 Gbytes, and the Sony WDD-931 stores 6.55 Gbytes. After five years of 650-Mbyte, 5.25-in. MO drive production, there's recently been an advance to 1.3 Gbytes by HP, IBM, Maxoptix, Sony, and others. The 3.5-in. drives are relatively new in the market, but capacity does appear to be generally settled at 128 Mbytes per cartridge.

There are no real interchange standards for 12-in. WORM drives, so that lack of agreement doesn't account for slow progress. However, the absence of a large market and its attendant R&D funds probably has had a major slowing affect. The 5.25-in. 650-Mbyte magneto-optical drives do have an interchange standard, so the "slowing affect" may be negligible in this case. Nonetheless, it does seem that optical technology has proven to be less readily extensible than magnetic technology.

The 4100 series developed by Philips LMS, Colorado Springs, Colo., is the nearest thing to a hot product in the 12-in. WORM drive world *(Fig. 6)*. It features dual heads so that both sides of the disk can be accessed without flipping the disk over. Also included is a fast-access five-cartridge magazine. Both of these features directly address and seek to correct the principal objection to optical disk drives-slow access to data.

Maxoptix, San Jose, Calif., came up with the T3-1300 MO drive featuring 1.3-Gbyte capacity, which is by far the fastest of the 5.25-in. optical drives. It features a 19-ms average seek time and 4800-rpm spindle speed. The internal cache buffer has a 4-Mbyte capacity. Like all magneto-optical drives on the market today, it still lacks direct overwrite capability. Therefore, one disk revolution must be devoted to erasing old data before new data can be written. Even this relatively fast optical drive poses no threat to the magnetic hard-disk drive market, but has a certain market niche of its own.

Fujitsu's (San Jose, Calif.) M2511A is a leading 3.5-in. magneto-optical disk drive product. It bears ISO-standard 128-Mbyte capacity in a single-sided cartridge, while providing high performance in a small package. Drive dimensions are a compact 25.4 by 101.6 by 146.0 mm. The drive operates on only 10 W of power while featuring 30-ms average seek time, 3600-rpm spindle speed, a 256-kbyte buffer, and an embedded SCSI-2 interface.

TAPE DRIVES: STILL ROLLING

Computer-compatible versions of magnetic tape drives have been around since the first IBM versions in 1945. Eventually, the reel-to-reel tape drives settled on a half-inch-wide format, although there were 0.75-in and 1-in. formats in use for several years.

Quarter-inch-cartridge (QIC) drives didn't emerge until 3M Corp.'s version in 1971, and it took another ten years before there was widespread acceptance. During the mid-1980s, IBM introduced its 3480 half-inch cartridge with 18-track parallel access, which effectively sounded the death knell for reel-to-reel drives. Also during the same time, Exabyte Corp., Boulder, Colo., became the first company to successfully market helical scan video tape drives adapted for data use (initially it was 2.2 Gbytes formatted, now it's doubled). Other companies tried this approach in the past but they were unsuccessful, in large part due to excessive data error rates.

Exabyte's timing was right because of the availability of new, powerful, and low-cost error detection and correction techniques using low-cost silicon chips. Moreover, Exabyte was able to utilize the low-cost *miniature* helical scan mechanisms developed for the mass consumer market in camcorders. The resulting data storage was and still is the lowest cost per bit of any data-storage method. Data recovery is serial and extremely slow compared to disk, and also slower than either QIC or half-inch data cartridges. QIC cartridge drive designers haven't been idle, though. This format eventually will store 10.5 Gbytes using advanced MR heads. ED

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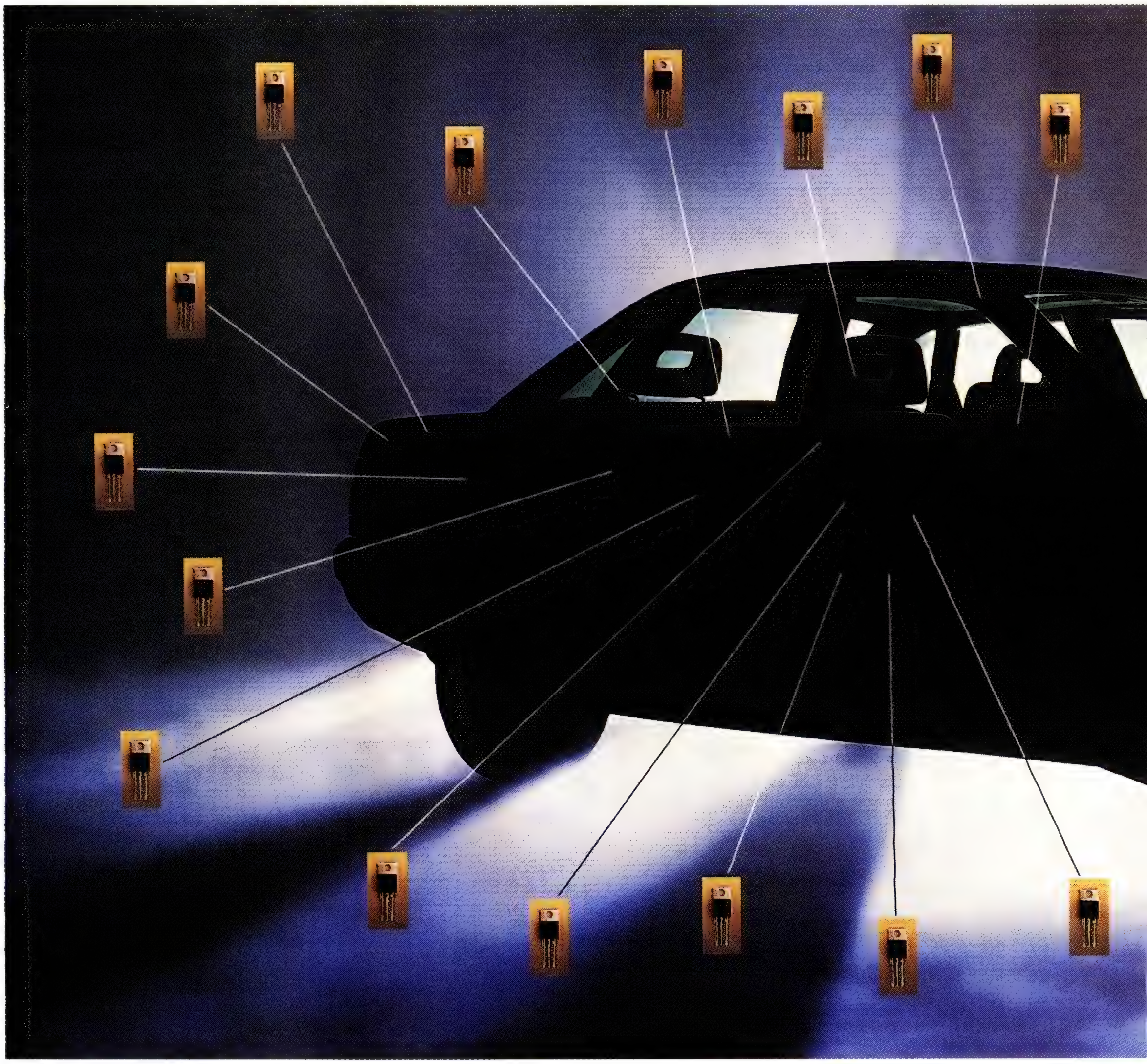

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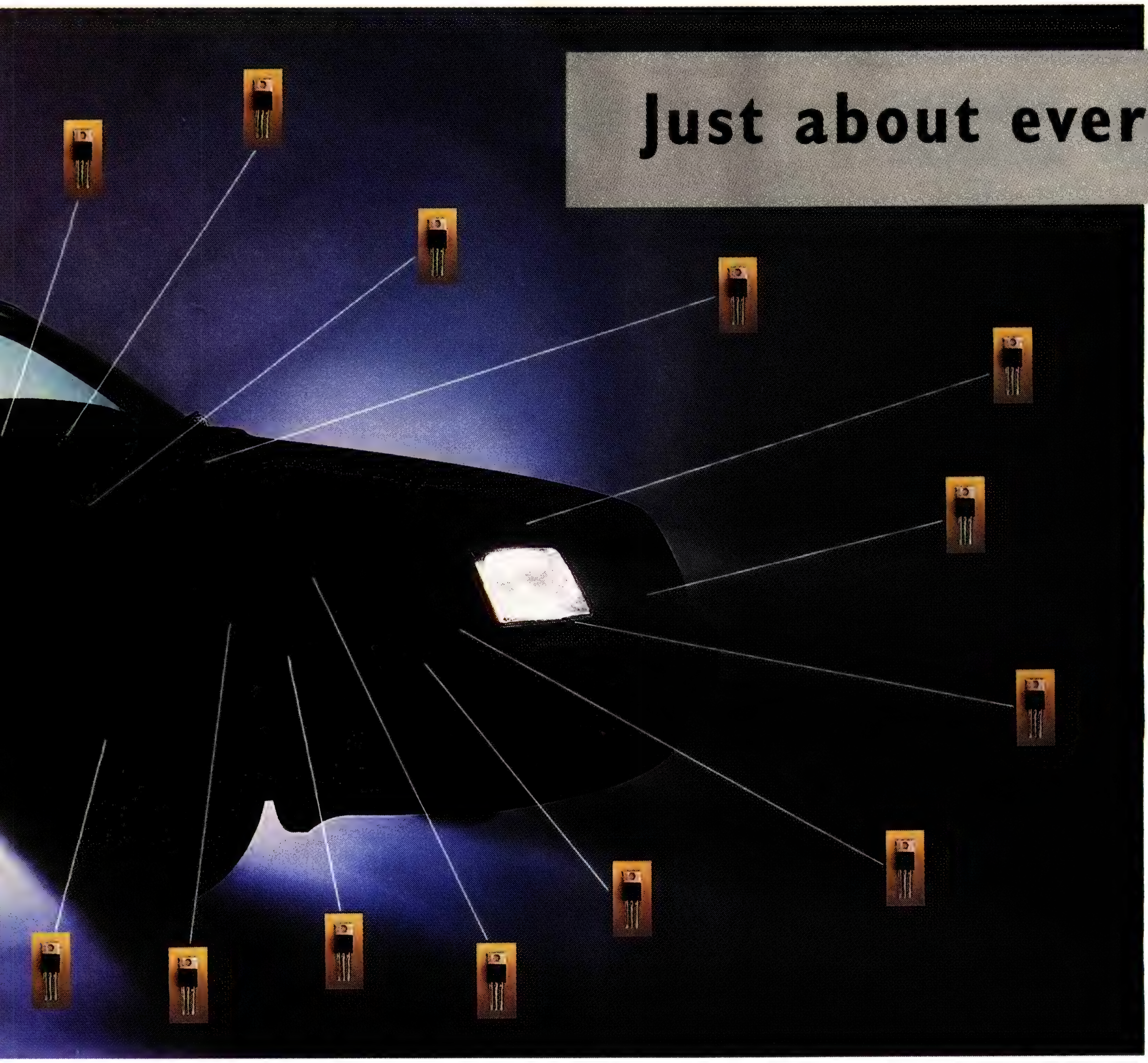

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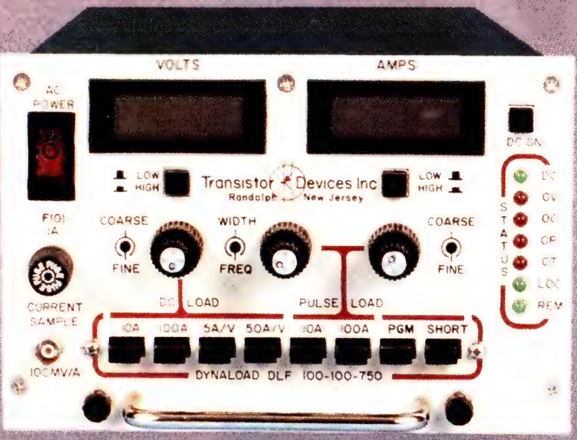

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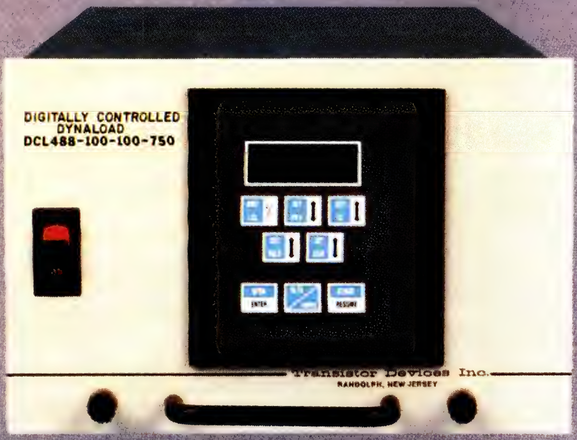

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DISK DRIVES STORE MORE IN LESS SPACE

CAPACITIES ARE ON THE RISE, EVEN AS FORM FACTORS GET SMALLER

Michael L. Workman
Senior vice president, hard drive research and development, Conner Peripherals

DISK DRIVES continue to play a major role in the information processing industry. Measured in revenue, the hard-disk-drive business will be about $10 billion dollars at the wholesale level, and perhaps three times that at the end-user level. For many companies providing desktop systems and/or workstations, hard drives account for 35% to 50% of their total revenue, an often much larger percentage of their profit, and between 15% to 20% of the total system cost. The prime driver of disk-drive cost for a given capacity is areal density (megabits per square inch). Fundamentally, until 1989, areal density grew at a 25 to 30% compound growth rate (CGR).

Translating to a doubling of capacity on a given disk area every 2.5 to 3 years, this rate made disk storage improve drastically from both an economic and a volumetric standpoint. It's interesting that until 1992, the price of a given drive fell at approximately the same rate as areal density increased. IBM started shipping magnetoresistive (MR) heads in 1990 to the OEM drive market, albeit in small quantities. The MR-head technology allowed a drastic areal-density increase of 50 to 60% CGR.

Two other technologies added to the volumetric density: constant-density recording, where the physical dimension of the smallest magnetized region on the disk is held constant as the radius increases from the inner diameter; and disk-to-disk spacing, which translates into more platters in a given form factor. Disk thickness and the size of the slider, two of which need to fit between the disks, are the main reasons for platter stack height. Companies are stacking as many as 10 platters in a 1.625-in.-high standard 3.5-in. diameter disk drive. Seagate has even announced a 12-platter, 1.625-in.-high device, to be available in mid-1994.

While MR technology provides advantages over thin-film-inductive (TFI) heads, coupling TFI heads with constant density recording and closer disk spacing yielded the same or greater capacities than in drives that employed MR heads. Constant-density recording and physical packaging improvements bought time to counter MR technology for those without it. At the same time, engineers pushed the TFI-head-based technologies to counter the MR technology. Hence, there has been a 40% to 50% CGR in areal density. Sustaining this trend will be difficult, but in the interim, the cost and volume advantages go directly to the consumer. Again, the increasing CGR of areal density was followed by a price reduction of comparable size.

Media technology has also marched forward at a tremendous rate. To increase areal density, the media must support increasing coercivity, decreasing thickness, and defect densities that scale down inversely with areal density. Magnetic films are approaching 1 μin. in thickness for MR disks, and will drop to less than a half in the next few years. To increase coercivity beyond that achievable with simple cobalt-chrome, third and fourth metals are being added, such as tantalum, platinum, and others.

Fly height of the magnetic pole tips of the head, or MR stripe in magnetoresistive technology, is the most influential parameter in the recording system. Fly height is determined by the design of the air bearing surface of the head slider (the head "flies" due to hydrodynamic pressure created by the moving air layer at the disk surface) in combination with the force exerted by the suspension assembly that mounts the head to the actuator (the device that positions the heads on the disk's surface). A given fly height is allowed by the smoothness of the disk, and the relative curvature of what appear to the eye as perfectly flat disks.

While flying heights have steadily dropped over the last decade, current values are about 3 μin. (nominal) for TFI heads. MR heads have a much higher sensitivity to magnetic fields written on the disk, thus relieving some of the pressure to lower flying height. Head and disk overcoats (usually hydrogenated carbon), pole tip recession, and variations from nominal fly height all make flying reliably at reduced heights important to increase areal density. Air-bearing technology should extend to 1 μin. or so, but at that point, contact recording will probably take over.

Contact recording describes a situation where the media and head actually contact each other rather than remain separated by an air film. The technology represents a major hurdle, though. Wear characteristics must be phenomenal to support two surfaces rubbing on each other for many years without degradation. One promising alternative seems to be liquid interfaces, because they can support the load and provide a lower friction interface than two solids. Conner has invested in its so-called VISQuS technology for that reason, and has demonstrated the technology with sub-1-μin. magnetic spacing. Such designs will not appear in the marketplace for some time, however.

Read-channel electronics is becoming more sophisticated every day, featuring some of the improved techniques used in advanced modems and satellite communications. Adaptive equalization and maximum likelihood detectors are used today, with Trellis codes looming on the horizon. Speed, not error-rate performance, is the limiting factor of read channels. Data rates to and from the media are approaching 100 megatransitions per second on high performance disk drives, and biMOS or CMOS processes that can maintain extreme timing tolerances at this speed is a continual challenge. Data rates as high as 150 megatransitions per second will be required in the next few years.

REAL-TIME & EMBEDDED SYSTEM OUTLOOK

ONCE CONSIDERED NICHES, THEY ARE NOW FINDING THEIR WAY INTO THE MAINSTREAM

Dr. Inder M. Singh
President, Lynx Real-Time Systems Inc.

UNTIL RECENTLY, real-time and embedded systems were viewed as arcane and relatively static market niches, characterized by specialized technology such as microcontrollers, special-purpose minicomputers, and assembly-language programming. Today, real-time and embedded systems are moving into the mainstream—they're no longer just for nuclear power plants, spacecraft, or factory robots. In fact, real-time systems surround all of us. They're hidden inside our dashboards, laser printers, and cellular phone systems, not to mention cutting-edge technologies like multimedia, virtual reality, and interactive video. And real-time embedded systems will be a key component in the much-heralded coming convergence of the communication, entertainment, and computer industries.

As the traditional computer markets go through a painful process of maturing, embedded products are becoming one of the most promising growth market segments. According to International Data Corp., Framingham, Mass., the high-end (16- and 32-bit) real-time and embedded software market alone will grow from $876 million in 1990 to $3.57 billion in 1995.

Microprocessor manufacturers are increasingly looking toward embedded systems for growth now that every desktop seems to have a computer—a saturation that's dampening growth in this market. This new marketing emphasis along with user demands for more intelligent and user-friendly products is driving the development of many new, highly intelligent products. As a result, the industry's need for programmers who can produce the required software will escalate.

Moreover, these embedded applications are becoming much more complex, software-driven projects that look increasingly like mainstream computer systems. Instead of microcontrollers with a few kilobytes of firmware, the newest embedded products sport 32-bit CISC or RISC CPUs, and complex applications software.

This mainstreaming means that, besides special requirements such as hard real-time performance, ROMability, and interfacing to various hardware devices, today's embedded software developers must deal with all issues pertaining to mainstream software systems, such as standards, user friendliness, software life-cycle costs, portability, object-oriented techniques and high-level programming languages like C++, and connectivity to non-real-time computer systems.

To support this new generation of real-time systems, developers are turning to commercially available, full-featured real-time operating systems instead of "rolling their own" real-time kernels. While the old real-time world was particularly fragmented with dozens of these awkward proprietary kernels, the new mainstream real time is ripe for standards. The POSIX 1003.4 real-time extensions standard, approved in its final ballot this past May, is about to be ratified as an IEEE standard. These real-time extensions, along with the POSIX 1003.1 base standard, will provide for the first time a standard API (application programming interface) for real time. This means that the newer, mainstream embedded applications can have the same portability that the non-real-time world has had for a decade.

As a result, POSIX standards and the resulting open systems will play a major role in assuring such mainstream capabilities as vendor independence, preservation of software investment, interoperability, and costs of software development and maintenance.

The proprietary "roll-your-own" kernels were notoriously time-consuming and particularly hard to program and maintain (some of them required assembly programming). That limited the number of available programmers, and made for applications that could not be migrated from one microprocessor to another.

Clearly, to meet the demands of the increasing number of mainstream embedded applications requires standard, POSIX-compliant operating systems that run on all major CPUs and applications programmed in mainstream languages, such as C and C++. The dramatic price/performance improvements provided by the latest 32-bit CPUs and the falling prices of memory chips have made software-intensive embedded products with POSIX-compliant operating systems affordable, even for high volume, cost-sensitive applications.

We have found, for example, that LynxOS, a UNIX/POSIX compatible OS, is being designed into dozens of products like printers, copiers, medical instruments, multimedia products and communication devices, something that appeared preposterous a few years ago.

The current battle raging between the major CPU architectures, like that between the Intel x86, PowerPC, and Sparc, along with the growth of the notebook and emerging personal-digital-assistant (PDA) markets are helping fuel the "mainstreaming of real time." These high-volume markets require highly integrated, low-power CPUs and supporting chip sets that are software-compatible with the leading PCs and workstations. These are also very attractive for embedded and real-time applications.

As high volumes drive down prices, embedded applications will increasingly be designed around these CPUs and chip sets from the PC and workstation worlds. In fact, they will appear even more like embedded versions of mainstream computer systems. ED

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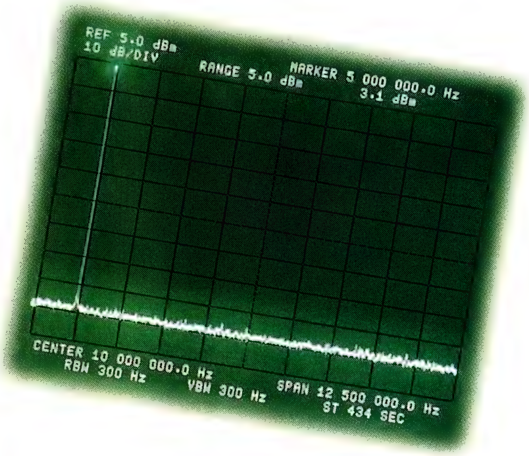

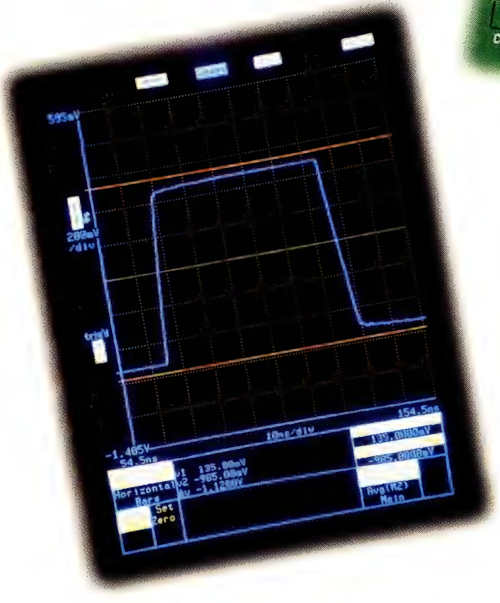

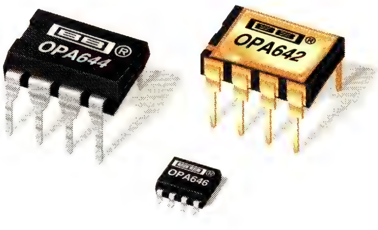

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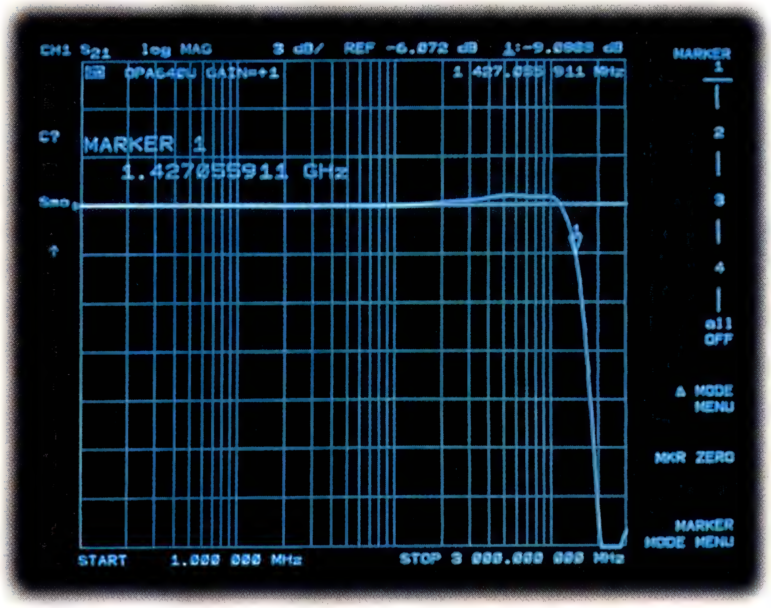

World's Highest Bandwidth, 1.3GHz
OPA640 is the world's highest bandwidth op amp! Its speed and dynamic performance make it your best choice for critical communications and test equipment applications.

PLUS

OPA640 Key Specifications

- Bandwidth ....1.3GHz at G=+1
- Voltage noise..........................2.9nV/√Hz
- Low harmonics ....–82dBc at 5MHz
- High CMR......................................85dB
- Demo board available
- Packages: 8-pin DIP, SOIC, Ceramic

1.6GHz Gain Bandwidth at G=2
OPA641 is stable in gains of two or greater and features a fully symmetrical input stage and high slew rate. Try it for RF and imaging designs.

PLUS

OPA641 Key Specifications

- Gain bandwidth ....1.6GHz at G=+2
- High slew rate............................700V/µs
- Low harmonics ....–80dBc at 5MHz
- Low noise ....3.0nV/√Hz
- Demo board available
- Packages: 8-pin DIP, SOIC, Ceramic

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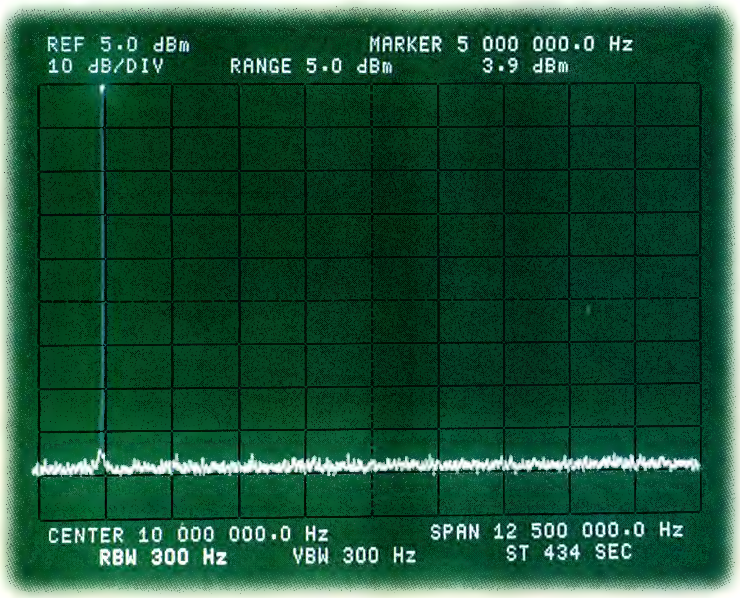
PLUS Low Distortion!



450MHz, 2.3nV/√Hz

OPA642 gives you high speed with very low distortion and noise—the right combination for your high resolution imaging applications.

PLUS

OPA642 Key Specifications

- Low harmonics.............–95dBc at 5MHz
- Fast 12-bit settling..........................13ns
- High A_{OL}..95dB
- Low diff gain/phase error......0.006%/0.008°
- Demo board available
- Packages: 8-pin DIP, SOIC, Ceramic

1.3GHz Gain Bandwidth at G=5, 94dB

OPA643 is stable in gains of five or greater, and offers minimum DC and AC errors. It's purely perfect for all preamp applications! Use it when you need low noise and high slew rate.

PLUS

OPA643 Key Specifications

- Gain bandwidth ....1.3GHz at G=5
- Low harmonics ....–90dBc at 5MHz
- High slew rate 1000V/μs
- Low noise ....1.8nV/√Hz
- Fast 12-bit settling...........21ns to 0.01%
- Demo board available
- Packages: 8-pin DIP, SOIC, Ceramic

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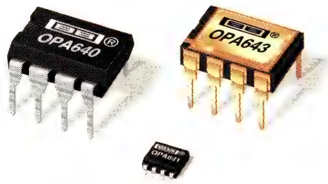

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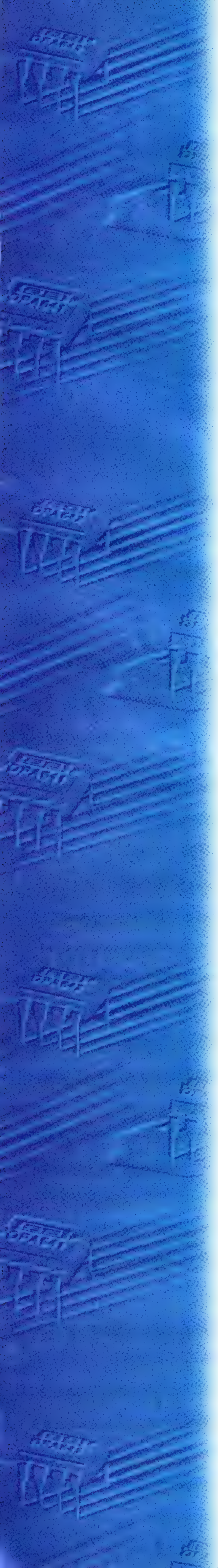

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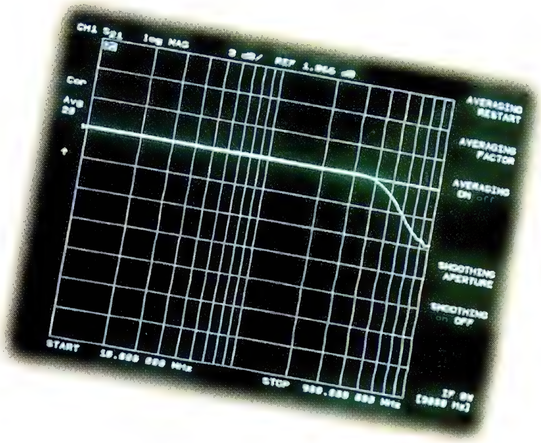
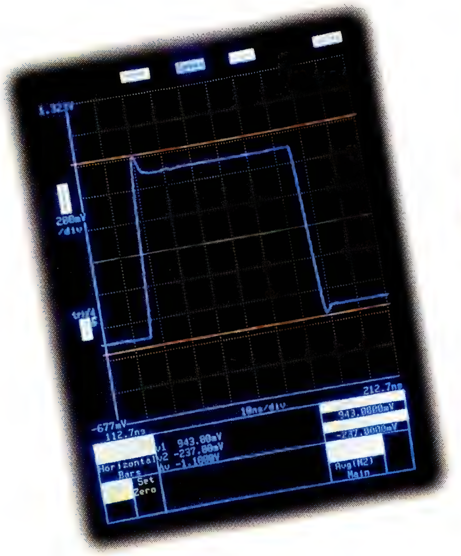
High Slew Rate!

PLUS

Low Power!





2500V/µs, –85dBc

OPA644's current feedback design gives you very high open loop transimpedance with high slew rate and superior differential gain/phase error. It's perfect for video, RF, and other high speed signal processing uses.

PLUS

OPA644 Key Specifications

- High bandwidth 500MHz
- High open loop transimpedance 2.0MΩ
- Low differential gain/phase error ....0.008%/0.009°
- Low harmonics ....–85dBc at 5MHz
- Demo board available
- Packages: 8-pin DIP, SOIC, Ceramic

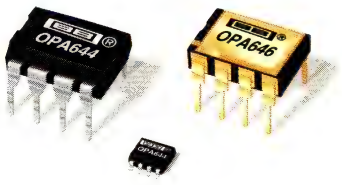
650MHz, 55mW

OPA646's wide bandwidth and low power simplify and improve a wide range of portable instrumentation, medical imaging, communications, and similar signal processing applications.

PLUS

OPA646 Key Specifications

- Low harmonics ....–82dBc at 5MHz, $R_L = 400\Omega$
- Low input bias current 2µA
- Fast 12-bit settling...........15ns to 0.01%
- Demo board available
- Packages: 8-pin DIP, SOIC, Ceramic



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CIRCLE 169 FOR U.S. RESPONSE

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OPENING NEW, UNTAPPED MARKETS FOR PCs

THE PLUG AND PLAY INITIATIVE WILL SEAMLESSLY ADJUST TO THE ENVIRONMENT

Moshe Lichtman
Group manager, Plug and Play, Microsoft Corp.

THE PC INDUSTRY has reached a critical junction in its evolution. On one hand, hardware and software continue to set new performance and cost records. But, the primary market for PCs—professional workers and corporate users—is relatively saturated, limiting growth opportunities for software and hardware vendors. This trend is compounded by the shrinking margins due to commoditization and fierce price wars. Now the stage is set for what will be one of the most significant efforts in the PC industry in this decade: the Plug and Play Initiative.

There's a new level of cooperation and dedication by many companies, which are otherwise intense competitors, in developing the Plug and Play Initiative. The vision of Plug and Play (PNP) is simple: the PC, peripherals, and software constitute a "no-brainer" appliance that seamlessly adjusts itself to its environment, allowing the user to fully concentrate on productive chores. The removal or addition of one or multiple devices, dynamically or statically, is immediately recognized and communicated through the system. New devices are automatically configured and drivers are dynamically loaded/unloaded. Also, applications make smart decisions based on the resources available at each point in time without bothering the user with cryptic dialogues or confusing error messages.

With a PNP PC, a mobile user can insert the PC into a docking station while it's running and immediately connect to a network, play a CD-ROM, and print documents spooled earlier. Installing new devices will no longer be reserved for support personnel, hardware engineers, or users who must "camp" on vendors' support lines. Applications will change their behavior based on the user's location or the PC's configuration. An E-mail application will automatically revert to slow-link mode when the modem, not the Network Interface Card (NIC), accesses the network.

One of the biggest differences between a PNP system and an existing system is the harmony and cooperation between the various components that make up a PC. In an existing system, the PCMCIA bus knows nothing about the ISA bus or the system-board devices. So, during the boot process, the PCMCIA software takes over a portion of what it thinks are the available resources, possibly preventing the user's ability to smoothly add ISA or system-board devices later on. There's also very little glue between the various buses, the devices, the operating system, and the software applications. As a result, when you insert a fax/modem card into a PCMCIA socket, no one notifies your E-mail package it may now dial up to your corporate network and download E -mail messages. The situation gets more complex with advanced buses such as PCI, which will need to support ISA devices for backward compatibility.

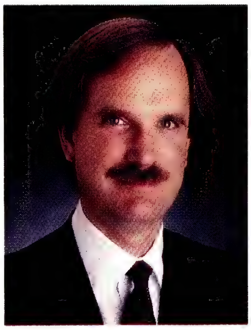
The Plug and Play Initiative is a broad industry effort to define an all-encompassing framework that will put some sense in the tangle of buses, devices, device drivers, BIOS, operating systems, and software applications that go into the PC. The beauty of PNP is that it doesn't compromise the openness of the PC platform. In the PNP framework, buses and devices are represented as nodes in a tree. The tree structure provides the missing link between the various components. Buses are abstracted from the operating system via bus drivers that communicate with the operating system and software application through a common API. Generic enumeration and configuration messages are then translated into bus-specific operations. Supporting a new type of bus requires only the addition of a new bus driver. All of the configuration and functional schemes remain the same. Even device drivers may stay the same if they use the common PNP APIs rather than bus-specific schemes.

One of the PNP framework's most important aspects is the requirement that devices and buses identify themselves and describe their requirements to the operating system. This is critical to achieving seamless PC configuration and operation. Once the device is identified, the operating system can load the appropriate devices, allocate the necessary resources (avoiding conflicts with existing devices), and notify applications about the new capabilities. In a PNP system, the BIOS is the system board bus driver, enumerating the embedded devices (including the expansion buses). It notifies the operating system of a docking event and provides information on current location (home, office). Each expansion bus has a dedicated bus driver that performs similar operations during boot and run time.

Rather than redesigning each hardware and software component, the PNP framework leverages existing schemes, and where necessary, provides guidelines or recommends incremental hardware changes. For example, because the ISA bus lacked an identification and configuration scheme, a group of companies led by Intel and Microsoft created the Plug and Play ISA specification that's available at no charge. A similar specification defining the BIOS interface in a PNP system is about to be released by Compaq, Intel, and Phoenix Technologies. Because the PCMCIA specification already provides the means for identification and configuration, the effort has focused on highlighting minimum PNP PCMCIA-card requirements. In fact, in the PNP framework, Card Services is the bus driver for the PCMCIA bus. Similar specifications are being developed by Adaptec, Future Domain, Hayes, IBM, Intel, Sony, Western Digital, Xircom and many others to address PCI, MCA, SCSI, IDE, and parallel and serial devices. ED

WHAT'S IN STORE FOR EMBEDDED SOFTWARE

MOST PREDICTIONS IN THIS FIELD ARE RISKY, BUT SOME TRENDS ARE CLEARLY DEFINED



Jim Ready
President,
Ready Systems

Some years ago, a group of young engineers and I put together a business plan for a software company. When a so-called "industry expert" evaluated our plan, his comment was that microprocessors were good only for "jukeboxes" and other trivial applications. In his mind, real men used mainframe computers. Our insight, which turned out to be true, was that the future of embedded computing centered on the microprocessor, and it would be only a matter of time until this became obvious.

It's easy to see why the microprocessor so dramatically altered the way systems were built. Take automobiles, for example. During the first gasoline crisis, many predicted that if cars were driven in the future, say 1993, they would be very small, possess tiny engines, and performance would be negligible.

As usual, however, it's difficult to predict the future. What the "doomsayers" failed to anticipate was the dramatic effect microprocessor control would have on the efficiency of automobile engines. As it turns out, tremendous optimizations could be made if sufficient computations could take place as the engine was running. The result is that today's cars get substantially better mileage with lower emissions and have equivalent or better performance than cars built 25 years ago.

Although automobiles are used as an example here, the same kind of benefits gained from incorporating embedded microprocessors applies to a wide range of manufactured items. Telecommunications, medical electronics, HDTV, appliances, factory and office automation, and other applications all depend on, or will depend on, embedded microprocessors to function properly.

But, coupled with every advance is the cost factor. As more and more of the applications' functionality shifts to software, companies are discovering that software development is taking an ever-increasing bite out of their development dollars. There are several reasons why this is happening (and inevitable). First, the applications are becoming more ambitious—that is, the feature set is expanding. If you have shopped for a VCR recently, it's clear that products aren't getting any simpler to use.

Second, the experience base in software within a given company may not be very deep. An engineer who may have began his career working on software-less projects may now be handling a project with hundreds of kilobytes of embedded software. It's possible that upper management has little or no experience in developing software and may be insensitive to the management challenges involved in a software-intensive project.

Finally, there are nonlinear effects that may catch management by surprise when moving from one level of complexity to the next. For example, a successfully completed project that uses an 8-bit microcontroller programmed by one individual doesn't mean that those same techniques scale to a design based on a 32-bit microprocessor with a 5-person programming team.

What can we say about the future trends in embedded computing? Of course, I'm probably just as fallible about predicting the future as the previously mentioned industry expert. However, I do think it's safe to say the following:

The software content of all kinds of devices will continue to grow dramatically. Although semiconductor makers are responsible for the ever-increasing power of microprocessors, marketing departments consume it by specifying more and more software-based features in new products.

Successful companies will put in place specific strategies to maximize the efficiency of their programmers, who will concentrate on application-specific programming. Partner companies will be selected to supply tools and application infrastructure software, such as operating systems and development tools to build the customer's applications. No one company can do it all any more.

Successful companies will also adopt external and open standards, as well as establish internal standards for the reuse of software and programmers across projects, product lines, and, for larger companies, divisions or business units. Quality standards, such as ISO 9000, will be a requirement for doing business, both for the embedded-system maker and its partner companies.

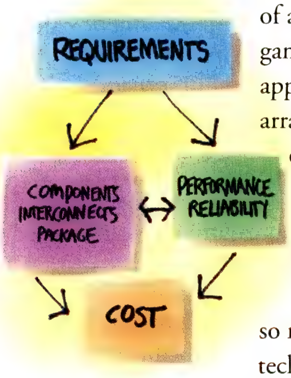
Products and technologies that are aimed at preserving companies' large investments in code and tools will emerge, with more emphasis placed on upward compatibility and assured migration paths.

We see a requirement for products that supply the user with an open environment, resulting in modularity, portability, and scalability. Often, when a software developer moves from one embedded project to another, he or she is compelled to learn a new real-time operating system, new tools, or new techniques. The cost of this repeated learning curve within a major organization is staggering. The solution is an open environment that allows users to extend their off-the-shelf environment by adopting their own in-house software, including kernels, tools, and utilities.

As for Ready Systems, our path is clear. We're well positioned to become a partner with our customers by supplying technology and products based on open industry standards. These standards will uniquely allow our customers to put in place the development environments and advanced run-time systems necessary to meet the challenges of developing tomorrow's embedded systems. ED

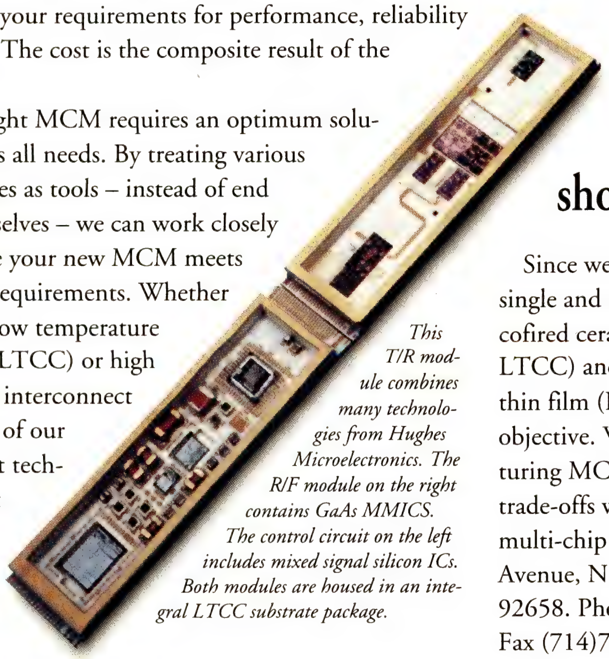
Are multi-messages on multi-chip modules confusing you?

Today, everyone agrees that MCM packaging significantly enhances performance while reducing weight and space in a wide range of applications. MCM's can run the gamut of digital, analog and microwave applications, military avionics, active array radar, GaAs MMICs, automotive electronics, industrial/commercial electronics, heart pacemakers and defibrillators, signal and data processors, cellular communications systems and many more. But, with so many choices, which MCM technology is right for you?



Remember, an MCM is a system comprised of the components, the interconnects and the package – all of which are selected based on your requirements for performance, reliability and affordability. The cost is the composite result of the selections made.

Defining the right MCM requires an optimum solution that addresses all needs. By treating various MCM technologies as tools – instead of end products in themselves – we can work closely with you to assure your new MCM meets your application requirements. Whether your MCM uses low temperature cofired ceramics (LTCC) or high density multichip interconnect (HDMI) or some of our other interconnect technologies, the right MCM solution evolves from a needs-oriented analysis.



This T/R module combines many technologies from Hughes Microelectronics. The R/F module on the right contains GaAs MMICS. The control circuit on the left includes mixed signal silicon ICs. Both modules are housed in an integral LTCC substrate package.

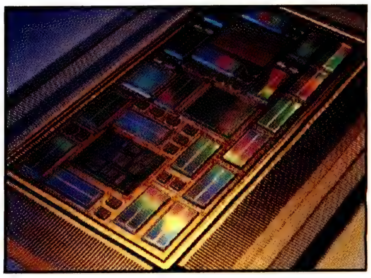
What's LTCC?

LTCC is a variant of MCM-C which fires at temperatures low enough to use noble metals such as silver or gold. It accommodates a variety of packaging needs. Extremely low profile packages are created by using cavities to hold silicon or GaAs semiconductors. Heat is dissipated by placing high power devices on thermal vias or a heat spreader attached to the back surface through a hole or cavity. By burying resistors, capacitors and inductors with a broad range of component values and tolerances, substrates/packages actually become large passive ICs.

What's HDMI?

It's a thin-film multilayer technology essential for the next generation of high-speed miniature electronics systems as used in computers, workstations and signal and data processors.

Which MCM technology should you use?



This 32-bit signal processor is a 20-MIPS general purpose processing element combined with nineteen 1-meg SRAMs, 1 EEPROM plus a 1-micron gate array ASIC – all packaged in a 2 x 4 inch MCM.

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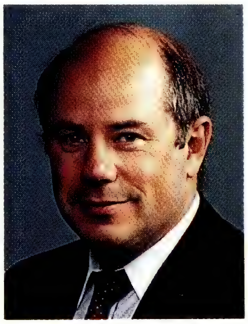
CIRCLE 102 FOR U.S. RESPONSE

CIRCLE 103 FOR RESPONSE OUTSIDE THE U.S.

THE NEW FRONTIER FOR DATA STORAGE

INCREASING FLASH CAPACITIES OPEN UP DOORS TO NEW PORTABLE APPLICATIONS



Eli Harari

CEO, SunDisk Corp.

WHEN THE INDUSTRY'S first 5.25-in. disk drive hit the scene, the OEM price was $1500 for a 5-Mbyte drive ($300 per Mbyte). The subsequent explosion of the PC market, with its voracious use of hard-disk drives for mass storage, propelled the disk-drive industry to the point where today, a 250-Mbyte drive can be purchased for under $250. That scenario will replay itself with solid-state storage over the coming decade.

However, this time, the driving force will be an explosion of handheld devices, starting with palmtop computers, personal digital assistants (PDAs), and personal communicators. It will then proliferate into consumer electronics (digital cameras, voice recorders), information appliances (such as information kiosks at airports), entertainment (games, multimedia), automotive (navigational), and home appliances. These vast new markets will take 5 to 10 years to blossom: That's how long it takes to establish the infrastructure, particularly in wireless communication, new distribution channels, and user education.

One of the keys to the solid-state storage explosion will be flash memory, perhaps more so than any other storage medium, including DRAM or hard-disk drives. Flash has no fundamental physical barriers through at least the next three generations, taking us to a 1-Gbit (128-Mbyte) chip.

Seeing the inevitable merger of computing and communicating devices, SunDisk's designers searched for a new solid-state mass-storge device to handle storage of programs, files, and data in new portable computing platforms. This device had to feature high reliability, low power, ruggedness, compatibility with MS DOS/Windows and other operating systems, removability for interchangeability between the handheld and the desktop PC, and full compliance with internationally adopted card standards.

What resulted is the FlashDisk. FlashDisk is a credit-card-sized PCMCIA (Personal Computer Memory Card International Association) solid-state disk that's 5 mm thick and weighs about 1 oz. FlashDisk has the characteristics of a high-performance removable hard-disk drive, yet it can be dropped from a height of 8 ft. onto a concrete floor without losing any data. SunDisk's FlashDisks come in storage capacities from 1.8 to 40 Mbytes. Software compression can increase the effective storage capacity to 80 Mbytes. In developing the FlashDisk product family, SunDisk received technical support from strategic partners such as AT&T, Matsushita, and Seagate, as well as from OEMs, including IBM and Hewlett-Packard. FlashDisk was created because early on it was realized that meeting the mobile world's stringent requirements called for a new solid-state memory system to be developed from the ground up. DRAM and SRAM, by virtue of their volatility (SRAM also because of its high cost) were deemed unsuitable for low-power battery operation. Small form-factor disk drives were too power hungry and not sufficiently rugged.

In terms of storage, handhelds and personal communicators require no more than a few megabytes. The price for such storage to the end user should not exceed one-third to one-half the price of the handheld itself. Although FlashDisk storage is relatively expensive today, the price will drop dramatically as the megabytes per wafer are doubled and quadrupled in the next-generation flash technology.

To achieve high reliability and data integrity in the mobile world's rough environment, SunDisk developed an integrated intelligent controller that's included on each FlashDisk card. This controller provides all the functionality of IDE (Intelligent Drive Electronics) in today's rotating disk drives, including I/O, file management, error correction, error recovery, power management, diagnostics, and other control functions optimized for the proprietary flash media. By eliminating all mechanical components, the FlashDisk has an estimated mean time between failures exceeding one million hours. It may be the most reliable mass-storage product commercially available today.

By using power-management techniques in the flash-memory cards, the battery life of the host system can be extended. For example, the controller automatically shuts off power to all flash chips on the FlashDisk card at all times between read/write operations. Due to the nonvolatility of flash memory, data retention can be extrapolated to over one million years at room temperature. Of course, no backup battery is required on the FlashDisk card, unlike SRAM.

Total compatibility with DOS and Windows and other disk operating systems was achieved by having the flash-memory chips mimic the architecture of rotating disk drives (as opposed to mimicking the architecture of an EPROM or an SRAM chip). For example, the flash chips are partitioned into 512 bytes of data sectors, each sector also being provided with sector headers for storing controller system parameters and error correcting code (ECC).

In ten years, a user will be able to purchase, for under $300, a PDA that incorporates cellular digital communications (voice, fax, E-mail), personal organizer and PC functionality, a ground-positioning device, city maps, airline/train/bus schedules, and various entertainment and consumer information. And it'll all be stored on a 100-Mbyte flash solid-state card. In fact, with the rapid pace in semiconductor development, SunDisk foresees a 100-Mbyte Flash ChipDisk within less than a decade. When that level of functionality is reached, the number of units sold will overwhelm anything the PC industry has experienced over the past ten years. ED

RECENT ADVANCES IN STORAGE TECHNOLOGY

PORTABLE COMPUTING RAISES NEW CHALLENGES TO DISK-DRIVE PERFORMANCE

THE DATA-STORAGE industry has continually grappled with predictions from analysts that magnetic-storage densities are approaching their limit. All trends indicate that these analysts are wrong. Recording densities have grown, sometimes at accelerating rates, with no slow down predicted in the foreseeable future. The magnetic-storage industry, in fact, has been characterized by innovative technological developments that repeatedly redefine and extend its limits. However, for a complete understanding of the trends in the magnetic-storage industry, it's not enough to simply examine the newest technologies. Their impact on the computer industry as a whole must also be understood.

Amyl Ahola
Vice president of marketing and strategic planning, Seagate Technology Inc.

One of the dominant computer-industry trends is the constant reduction in the size of computer systems and their constituent components. As notebook computers begin to rival the performance of desktop machines, system designers are forced to incorporate powerful peripherals with smaller sizes. The disk-drive industry has successfully produced products with form factors of 2.5 in. Such drives offer capacities approaching 300 Mbytes, while boasting high performance and reliability.

The 2.5-in. form-factor drive has become the de facto standard storage medium for notebook and many subnotebook computer systems for two reasons. First, they provide the storage capacity and performance necessary to run demanding software applications. Second, they offer sophisticated power-management capabilities to extend the precious battery life of portable computers.

The rigors of portable computing have pushed storage peripherals beyond their capacity and performance. As users venture forth with portable computers, these machines become subjected to environments much harsher than their desktop counterparts. This places an added requirement of ruggedness on every system component.

Many drive manufacturers have attempted to develop designs that will mitigate the effects of shock. For example, Seagate Technology designed the SafeRite system, which can detect critical shocks and instantaneously respond by halting writes to the drive until the shock event subsides. When a notebook computer is dropped from 2 in. above a table top, a drive mounted inside can incur a shock of up to 80 Gs. Drives implementing the SafeRite sensor can support operating shocks of up to 100 Gs, while ordinary drives are limited to about 10 Gs.

Continuing the downsizing trend, drive manufacturers are now developing even smaller form-factor drives for use in subnotebook and handheld systems. These tiny drives are part of the new 1.8-in. form-factor, and most are PCMCIA (Personal Computer Memory Card Interface Association) compatible. The specification's latest release defines the interface characteristics for memory and storage devices ranging from disk drives to flash memory cards.

The original scope of the PCMCIA specification was to allow system designers of memory-card products to build compatible components. The most promising of these technologies are the flash, EEPROM, and solid-state memory products currently being developed by Intel, SunDisk, and others. Providing storage capacities from 1 to 40 Mbytes, these devices will become invaluable for the personal-digital-assistant (PDA) computing devices produced by such manufacturers as Apple, Sony, and Sharp.

With flash memory, users can store data in a rugged, easily portable unit about the size of a credit card. Although this form of storage is relatively expensive at the moment, these devices have key advantages for the portable computers. In addition to their small size, they're extremely rugged and consume 100 times less battery energy than a disk drive. This allows an unprecedented degree of removability and transportability. As the developments in technology continue to lower the cost per megabyte, flash will serve a larger portion of portable memory applications.

To meet the requirements for better performance, drive manufacturers are employing increasingly complex design techniques, including read and write caching of data, higher spindle speeds, and faster seek times. To handle this complexity, individual digital signal processors are assigned the task of controlling the servo functions while the main processor handles data and cache control. This multiprocessor architecture exists on many drives today, and will become a design necessity for future drives.

Surges in capacity are directly a function of the drive's areal density. One of the most significant recent innovations is the development of magnetoresistive heads, which increase the areal density on the drive's recording surface. The areal density of a drive is a measure of how much data can be accurately stored on the recording surface (or media). Current drives place 60,000 bits/in. on a track, with 3,000 tracks/in. on the media, resulting in a 180,000,000-bit/in.^{2} areal density. At these densities, 15 tracks of data would fit on the thickness of a single sheet of paper.

This heavy concentration on the downsizing while maintaining large storage capacities also has enhanced larger disk drives. Major drive manufacturers are currently shipping 5.25-in. full-height drives with capacities higher than 9 Gbytes. Accordingly, the 3.5-in. half-height (1.63-in. or 41.4-mm high) drives now boast capacities in excess of 4 Gbytes, with increasingly faster performance and data throughput.

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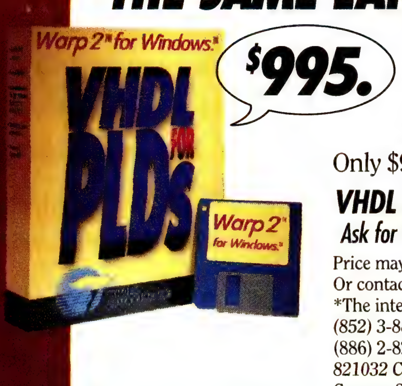
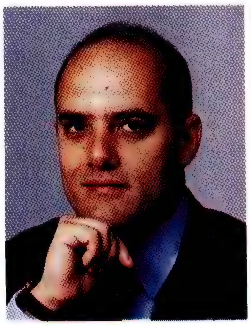


REAL-TIME SOFTWARE TO GET MORE COMPLEX

SEVERAL BIG IMPROVEMENTS LIE AHEAD IN THE AREA OF DEVELOPMENT TOOLS



David N. Wilner, vice president of engineering, Wind River Systems

IN THE EFFORT TO BRING new electronic products to market, no hurdle looms larger than software development. This certainly is the case in the field of real-time embedded software. The complexity of embedded systems—which control everything from car engines and aircraft guidance systems to phone switches and traffic signals—has grown prodigiously in recent years, owing to the spread of economical 32-bit processors. A typical 32-bit embedded program, consisting of thousands of software objects, must manage a variety of concurrent tasks, all interacting in complex ways and often running on multiple processors. To compound the challenge, product schedules are accelerating as companies race each other to market at a breakneck pace.

Now more than ever, embedded-software engineers need powerful tools to help them manage this complexity and streamline development. Some significant strides have been made in this regard over the last few years. Sophisticated cross-development environments, cross-compilers, source debuggers, incremental loaders, simulators, and other tools tailored to embedded systems all have helped speed, simplify, and economize the software design cycle.

More is needed, however. Developers of real-time embedded software face challenges only partially addressed by today's tools, and the next few years will see major improvements in a number of critical tool technologies. Particularly beneficial will be enhancements of four key capabilities: system visualization and analysis; graphical presentation of information; interactive, incremental development; and the scalability of development environments.

Visualization. With embedded systems becoming more complex, development methodologies improving, and code reuse increasing, developers are spending less time on writing and debugging sequential lines of code in a single module, and more time on systems integration—that is, on debugging interactions between modules, tasks, and entire subsystems. Traditional analysis and debugging tools fall short in two important respects. First, though they give access to microscopic details such as the contents of a particular memory location, they fail to provide much insight at the higher level of tasks and system events. Second, the information revealed by the tools is usually static—a snapshot of the system at an instant in time or a statistical average drawn from multiple snapshots. In real-time embedded systems, where discrepancies of a few microseconds may be fatal, static analysis falls short.

A strong need exists for analysis tools that give dynamic insight into the high-level events that most interest engineers. In recent years, debuggers have evolved from the machine level to the symbolic and source-code levels. The next step is the system level, wherein users can see the relationship and precise timing of events such as task switching, interrupts, and message-passing between tasks.

Presentation of information. Many of today's tools for embedded development lack graphical user interfaces, or if they have them, they're simply GUIs superimposed on command-line functions. So, for instance, an existing alphanumeric command is replaced by a mouse click. Far better would be true graphically based products that use visual models—graphs, diagrams, and charts—to help users better understand complex system relationships like those between objects. Such "object displays" could provide graphical presentation of data such as configuration parameters, object location, addresses, and statistics.

Interactive and incremental capability. Ideally, users should be able to create, test, and modify small sections of the code (such as individual modules), thus assembling a system through a process of rapid, incremental refinements. Unfortunately, many current development tools perform jobs in a long-turnaround monolithic fashion, where the developer is limited to compiling, loading, and executing whole programs. New tools—compilers, loaders, and interpreters—are needed to tighten the loop, allowing rapid prototyping, testing, and debugging.

Scalability. Lately, most of the growth in 32-bit, real-time embedded markets has occurred at the low end in products like automobiles and consumer products. In the future, software development tools will have to become more scalable to these smaller, leaner systems. Such systems often lack the large memories, high-bandwidth interfaces, and other hardware resources needed to support sophisticated tools. Today's development environments, which put some of the tool processing burden on the embedded "target" system, will have to shift more of the burden to a remote host computer, typically a Unix workstation or PC. Moreover, development environments should be flexible with regard to host-target connection strategies.

To satisfy the demand for embedded software in the ever-expanding universe of electronic products, breakthroughs must be capitalized on in the areas of systems visualization and GUIs. By using visual debugging and analysis tools that leverage cross-development environments, developers can see such events as task switches, interrupts, semaphore passing, and messages as they unfold. Bugs that in the past have delayed product completion by days, weeks, or even months can in many cases be dealt with in minutes. With advances like these in place, time-to-market cycles can be compressed and the industry can grow. ED

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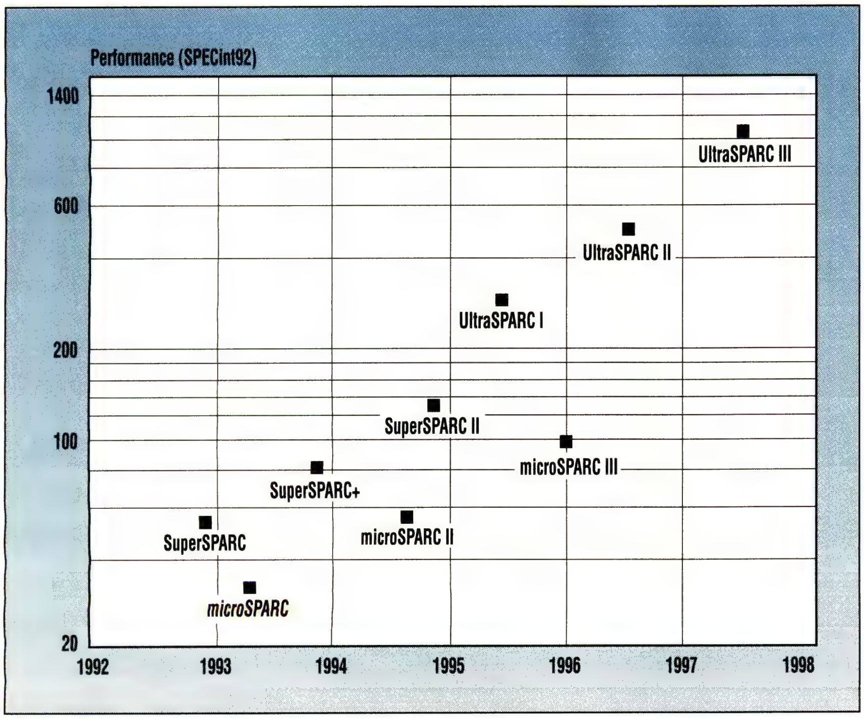
MICROPROCESSOR PERFORMANCE ONSLAUGHT PUSHES ON

ENHANCED CACHES AND ARCHITECTURES ARE KEY DRIVING FORCES.

BY DAVE BURSKY

THE BATTLE BETWEEN HIGH-PERFORMANCE RISC AND CISC microprocessors for use in desktop, portable, and departmental systems, as well as in embedded applications, seems to be hitting a fever pitch: Higher-performance and lower-power chips are popping up almost on a weekly basis. As superscalar architectures gain acceptance and caches hit 24 to 32 kbytes, CPU throughputs are achieving 50 to 150 million instructions per second (MIPS). And, by adding power management and migrating to 3.3-V supplies, CPU power-consumption levels are being trimmed. The 10 to 25 W per chip consumed by first-generation superscalar CPUs will soon drop to between 3 and 15 W when in the active mode, and to less than 1 W when in standby, for forthcoming-generation processors.

CPUs are performing more operations every cycle by incorporating lots of on-chip parallelism through a combination of superscalar and superpiplining approaches, which thus speeds up execution times. Wider data buses are also emerging. Already, chips such as Intel's Pentium and several RISC processors employ 64-bit data and address buses. And a few RISC chips—the SuperSPARC processor developed by Sun Microsystems and Texas Instruments (TI) and the Alpha processor from Digital Equipment Corp. (DEC), for example—are incorporating 128-bit-wide data buses. With these wide buses, internal cache lines can be replaced very quickly, reducing the delay when servicing a cache miss.



1. In its Sparc strategy, Sun Microsystems expects to develop future-generation processors that will improve on its current 60-to-100 SPECint92 processors by a factor of ten in about five years. The performance gains will be achieved through a combination of process improvements that permit shorter cycle times, new architectural concepts, and increased on-chip resources.

Advances in superscalar architecture implementations and finer-line processes that permit higher levels of integration, as well as the use of on-chip phase-locked loops to reduce external clock frequencies, give chip designers a well-packed arsenal to climb the performance hill. With the move to 0.5-μm features and three or more levels of metal interconnections, designers can build very dense and fast circuits that operate at frequencies of well over 100 MHz.

As a result, today's top-performance processors with 100 to 150 MIPS (60 to 100 SPECint92) peak performance will become the norm next year. And, in a few years, such chips will reside at the low-end of the performance spectrum as processor throughput levels move to several hundred MIPS and eventually to 500 MIPS and more for a single-chip CPU. Such performance directions were outlined by Sun Microsystems earlier this year when it unveiled its Sparc processor roadmap, which revealed five future generations that will deliver throughputs of over 1000 SPECint92 by the year 1998 *(Fig. 1)*.

To get such high performance levels, today's high-end CPU designs employ between 2 and 4 million transistors on one chip. Designs currently on the drawing boards promise to double that number by 1995, and will most likely double it again by 1997. At least half of the transistors on those super chips will be used for either the cache memory or the support circuits in the on-chip memory management unit. That would still leave several million transistors for implementing a highly parallel processor, or multiple processors on the same chip.

In one such example, Sun Microsystems just unveiled its microSPARC II processor with over three million transistors. The microSPARC II incorporates four times the cache of the microSPARC I, as well as other enhanced on-chip resources—power management, a multiplier for the floating-point unit, and larger write buffers. Yet with all that, it's actually smaller, runs faster (70 MHz versus 50 MHz), and on average consumes less power than the microSPARC I (ELECTRONIC DESIGN, *Nov. 1, p. 34)*. A key factor in this version is the use of a 0.5-µm triple-metal CMOS process, versus the 0.8-µm two-metal process used to make the microSPARC I.

Many high-end CPUs are also finding their way into embedded control applications. In a number of cases, the processor is the same one being used for the application it was initially designed for—desktop/deskside computer systems. But in other cases, the processor is optimized for control applications.

Optimizations include slimmed-down caches and data buses, reduced address spaces, added I/O support functions, or removed floating-point units or memory managers to lower power consumption and shrink chip area, which ultimately results in lower chip cost. Over a dozen RISC and CISC 32- and 64-bit CPUs are now optimized for embedded applications *(Table 1)*. Most incorporate various I/O support functions—counter-timers, DMA controllers, I/O control lines, interrupt controllers, etc.—to greatly simplify system design.

Most recently, both Advanced Micro Devices (AMD) and the team of Intel and VLSI Technology independently introduced highly integrated 386-based CPUs targeted at personal digital assistants (PDAs). Intel also released a highly integrated 80386 that's an upgrade to its decade-old 80186, the 386EX, which is targeted for embedded control *(Fig. 2)*.

In the RISC arena, processors such as the just-released Orion (R4600), jointly developed by Integrated Device Technology (IDT), Quantum Effects Designs Inc. (Santa Clara, Calif.), and Toshiba (ELECTRONIC DESIGN, *Nov. 1, p. 112)*, the 21068 version of DEC's Alpha processor *(*ELECTRONIC DESIGN, *Oct. 14, p. 98)*, and the established SPARC Lite from Fujitsu (ELECTRONIC DESIGN, *Nov. 8, 1990, p. 57)* have on-chip resources that are optimized for embedded applications.

Many companies are also turning the CPU into a mega-

TABLE 1: 32-BIT AND LARGER PROCESSORS FOR EMBEDDED CONTROL

(Ranked roughly by the highest-throughput member of family)

RISC processors or families for embedded applications

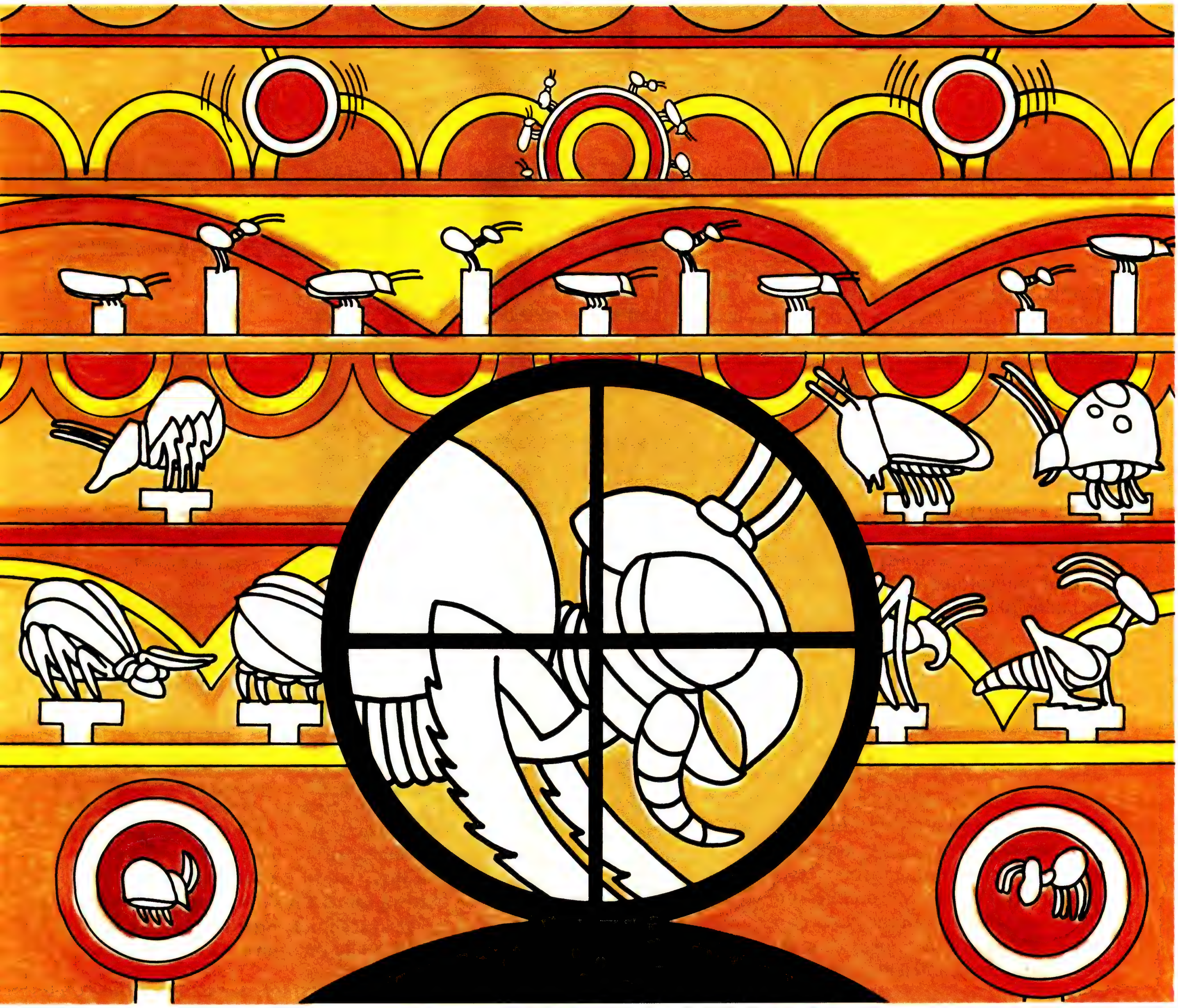
Alpha 21068	Designed and manufactured by Digital Equipment Corp.
PowerPC 4xx*	Designed and manufactured by IBM
T9000	Designed and manufactured by Inmos Div. of SGS-Thomson
PA-RISC	Designed and manufactured by Hewlett-Packard, Hitachi, and Oki
R4600	Defined by Quantum Effects Designs; licensed and manufactured by Integrated Device Technology (IDT) and Toshiba (MIPS-compatible)
SH 7000	Designed and manufactured by Hitachi Semiconductor
T800, 400	Designed and manufactured by Inmos Div. of SGS-Thomson
SPARC Lite	Designed and manufactured by Fujitsu Microelectronics
i860	Designed and manufactured by Intel
i960	Designed and manufactured by Intel
M88110	Designed and manufactured by Motorola
Am290xx	Designed and manufactured by Advanced Micro Devices
R305x	Core defined by MIPS Technologies; licensed, modified, and manufactured by IDT
R30xx	Core defined by MIPS Technologies; licensed, modified, and manufactured by LSI Logic
Am292xx	Designed and manufactured by Advanced Micro Devices
ARM	Defined by Advanced RISC Machines; licensed to and sold by VLSI Technology, Texas Instruments, Sharp, and GEC Plessey

*Intent announced; details not yet released.

CISC processors for embedded applications

NS32xxx family	Designed and manufactured by National Semiconductor
68EC0x0 family	Designed and manufactured by Motorola
ELAN 386	Designed and manufactured by Advanced Micro Devices
80386EX**	Designed and manufactured by Intel
Polar 386 (chip set)	Designed by Intel and VLSI Technology; manufactured and sold by VLSI Technology
VM386	Designed and manufactured by VM Technologies
683xx family	Designed and manufactured by Motorola

**Details released; samples not expected until early 1994.
This is not an all-inclusive listing, but it represents most known products.



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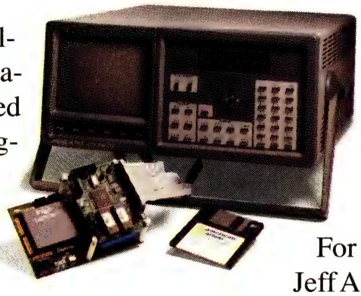

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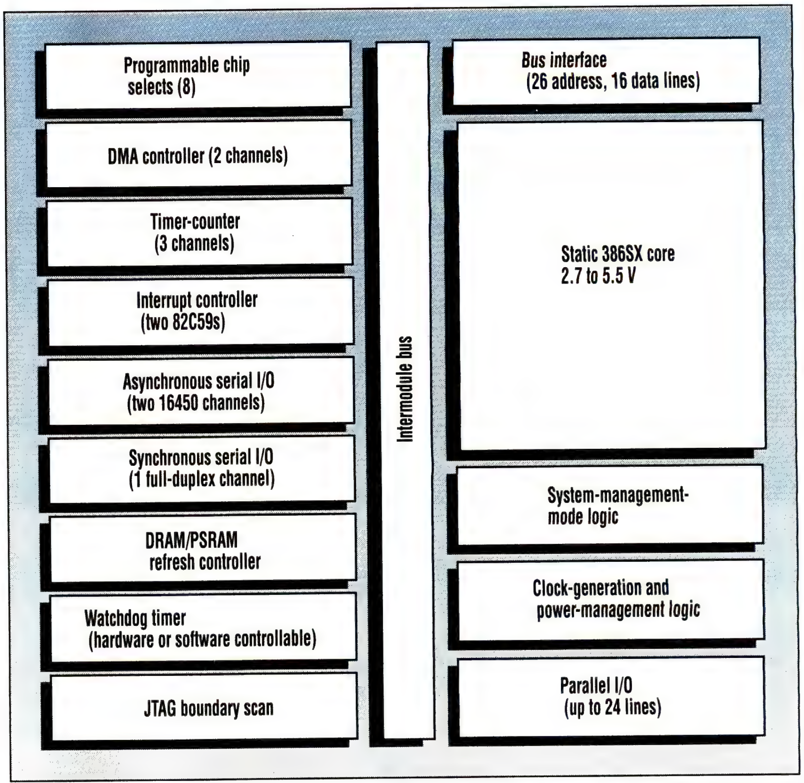
function as part of a cell library for application-specific chip designs. As a component of a cell library, designers can create application-optimized versions to tackle communications, printer control, or any other function. Examples of such capabilities include the 305x series of MIPS-compatible controllers from IDT, the MIPS-based CoreWare offered by LSI Logic, and the ARM core offered by GEC Plessey, Sharp, Texas Instruments, and VLSI Technology.


Programmable chip selects (8)
DMA controller (2 channels)
Timer-counter (3 channels)
Interrupt controller (two 82C59s)
Asynchronous serial I/O (two 16450 channels)
Synchronous serial I/O (1 full-duplex channel)
DRAM/PSRAM refresh controller
Watchdog timer (hardware or software controllable)
JTAG boundary scan
Intermodule bus
Bus interface (26 address, 16 data lines)
Static 386SX core 2.7 to 5.5 V
System-management-mode logic
Clock-generation and power-management logic
Parallel I/O (up to 24 lines)

2. Tackling embedded-control applications that need more horsepower than the 80186 family can deliver is the Intel 386EX. It can operate at supply levels ranging from 2.7 to 5.5 V. The device includes a superset of the 186's features plus a static 386SX core that runs at 16, 20, or 25 MHz (the 25-MHz option is for a 5-V supply). Like the 386SL, the 386EX includes the system-management mode and a reduced, 16-bit data-bus interface to keep the pin count to 132 leads.

The availability of both CISC and RISC processors poses a selection quandary for the designer since more than one CPU will have enough computing power to satisfy most applications. That applies to both computers and embedded-control systems. However, in the computer arena, there's a two-tiered struggle taking place.

On one tier, the battle is heating up between the x86-camp architectures (the IBM PC and compatibles) and RISC-based platforms (Sparcstations from Sun Microsystems and others; PowerPC-based systems from IBM, Apple, and others; IBM's RISC System 6000s; DEC's AXP Alpha systems; PA-RISC systems from Hewlett-Packard (HP) and partners; and R4x00-based systems from Silicon Graphics and others). On the second tier, there's a fierce battle raging between the companies that supply x86-architecture CPUs. And somewhere off in the corner are 680x0-based systems from Apple Computer Corp., Cupertino, Calif., and a few other companies, which are competing with both of the other camps for market share.

Although the RISC-based systems and the 680x0 systems do compete with the x86 for the desktop, the sheer volume of IBM PCs and compatibles manufactured—about 40 million systems per year—is more than an order of magnitude larger than the total number of 680x0- and RISC-based systems sold per year. Sun Microsystems, for instance, just celebrated the sale of its one-millionth workstation—quite a feat considering it started out as a very narrow area. But a total sale of 1 million units pales in comparison to *annual* sales of some 25 to 40 million x86 systems.

The availability of the Windows NT operating system developed by Microsoft Corp., Redmond, Wash., promises to create a new segment of computing that could bring about a new class of desktop computer. Such systems—mostly RISC-based—will deliver workstation-class performance at PC-like prices. To make that possible, many of the new RISC processors—the Alpha family from Digital Equipment and the R4x000 family defined by MIPS Technologies, for example—are optimized to efficiently run the NT operating system and to form low-chip-count motherboards *(for more on workstations, see related article on p. 29).*

However, the volume market for such systems may still be two years away, because it will take a long time for companies to evaluate NT and come up with a broad range of NT-optimized applications. Although systems that run NT can run any Windows application software in an emulation mode, performance won't be as good if the application was compiled into the processor's native instruction set. Thus, few people will buy an NT-based platform just to run popular Windows applications (although it could be a strong reason for a backup). However, Unix applications that run natively on the RISC processors should be relatively easy to port over to NT. Moreover, these applications, ranging from CAE tools to financial modeling, will be the initial drivers.

The one exception that may become a driving factor is the multitasking ability of the NT operating system. "Power users," frustrated by the single-tasking Windows OS, might jump to NT just to get more done by running several programs concurrently. NT, of course, will also run on 386 and newer x86-compatible CPUs, giving such systems the same multitasking capability. Not to be left out, Microsoft is al-

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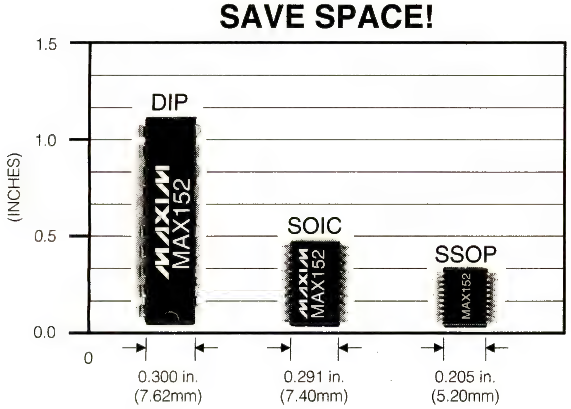

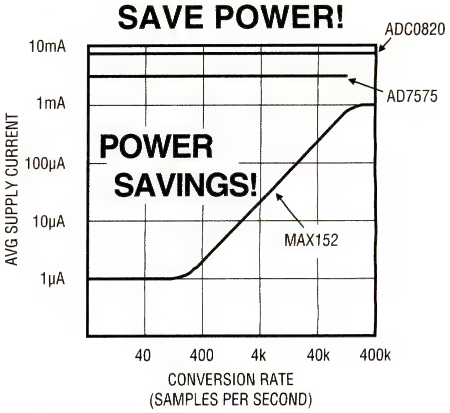

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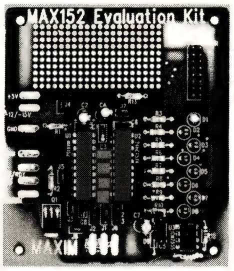

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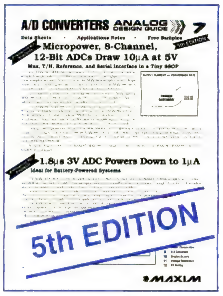

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ready demonstrating features of Windows 3.1's successor, code-named Chicago, which will also offer multitasking. However, it isn't expected to be released before the second of 1994.

FAMILY SQUABBLES

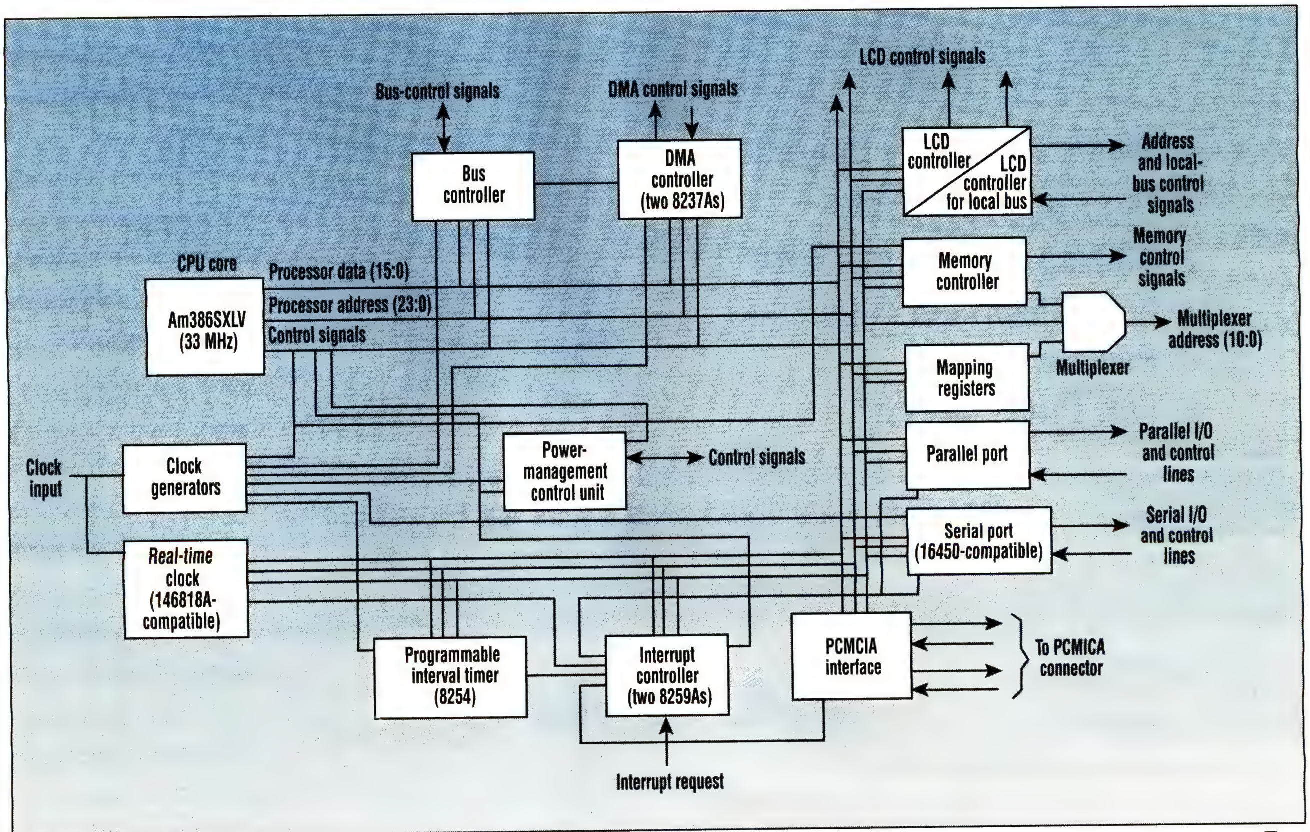
Not only is there a battle being waged between RISC and CISC, but each camp is having its own equally lively skirmishes. In the x86 desktop camp, for instance, there are now five alternate suppliers of Intel-compatible 386 or 486 processors, and Intel is doing some legal jousting with three of them—AMD, Cyrix, and TI. None of the three, claims Intel, are totally free of patent infringement. A fourth, VLSI Technology, struck a deal with Intel: The two jointly developed a highly-integrated 386SL-based chip set, called Polar, to be sold by VLSI Technology (ELECTRONIC DESIGN, *Oct. 14, p. 140)*. AMD also created a highly integrated 386-compatible processor for the handheld market, code-named Elan, that's based on the company's 386SXLV static 33-MHz CPU core *(Fig. 3)*.

The fifth supplier, IBM, is bound by contract not to sell its versions of the x86 architecture as standalone chips. However, it skirted around that contract limitation by selling motherboards and other cards that contain the CPUs. It has variants of the 386 and 486 microprocessor with on-chip caches and 16-bit data buses. The company's most recent development is a high-performance CPU code-named Blue Lightning, which includes a clock-tripling capability and full 32-bit buses. When running at 100 MHz internally (33.3 MHz externally), the chip delivers a throughput of between 40 and 50 SPECint92. Other companies, such as NexGen Inc., Milpitas, Calif., and VM Technologies, Tokyo, Japan, are expected to have specially developed instruction-compatible processors for vertical markets.

The array of CPU choices in just the 386- and 486-compatible market is becoming overwhelming as CPU suppliers offer a selection of speed grades, feature sets, and package options *(Table 2)*.

While the wars continued in the 386 and 486 camps, Intel put much effort into its next-generation processor, the three-million-transistor Pentium released earlier this year. When clocked at 66 MHz, the Pentium is roughly rated at 64 SPECint92 and 56 SPECfp92. And Intel has already given a glimpse of its future game plan—its next two-generation processors, referred to as the P6 and P7, will offer much higher throughputs and will require about 10 million and 30 to 40 million transistors, respectively.

In addition to the first-generation Pentium, designers at



3. This highly integrated processor with a static 386-compatible core processor is meant for handheld systems. Developed by Advanced Micro Devices, the all-in-one chip includes an LCD flat-panel controller, serial port, parallel port, PCMCIA interface, power-management logic, DMA and interrupt controllers, a real-time clock, and programmable timers.

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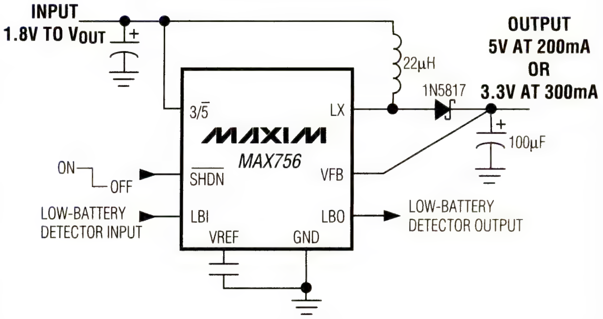
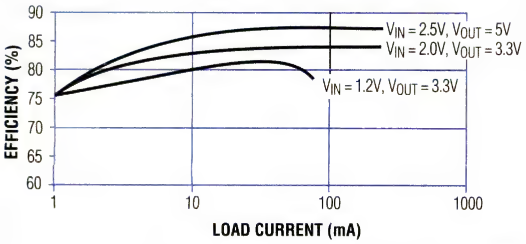


EFFICIENCY vs. LOAD CURRENT



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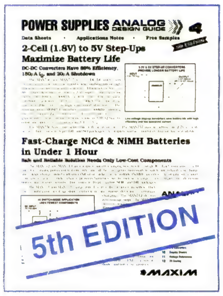
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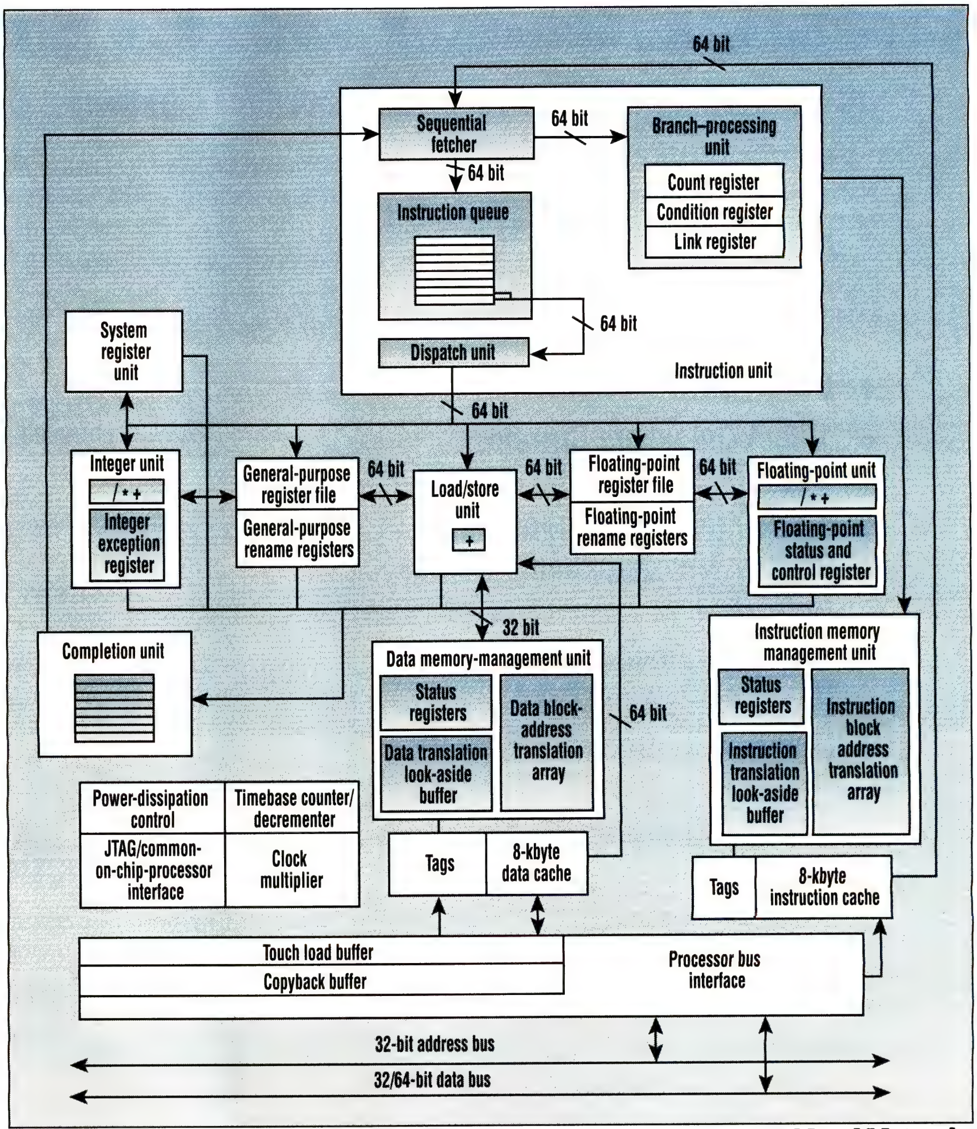
CIRCLE 193 FOR U.S. RESPONSE

CIRCLE 194 FOR RESPONSE OUTSIDE THE U.S.


64 bit
Sequential fetcher
64 bit
Branch–processing unit
Count register
Condition register
Link register
64 bit
Instruction queue
64 bit
Dispatch unit
Instruction unit
System register unit
64 bit
Integer unit
/ * +
Integer exception register
General-purpose register file
General-purpose rename registers
64 bit
Load/store unit
+
64 bit
Floating-point register file
Floating-point rename registers
64 bit
Floating-point unit
/ * +
Floating-point status and control register
32 bit
Completion unit
Data memory-management unit
Status registers
Data block-address translation array
Data translation look-aside buffer
64 bit
Instruction memory management unit
Status registers
Instruction block address translation array
Instruction translation look-aside buffer
Power-dissipation control
Timebase counter/ decrementer
JTAG/common-on-chip-processor interface
Clock multiplier
Tags
8-kbyte data cache
Tags
8-kbyte instruction cache
Touch load buffer
Copyback buffer
Processor bus interface
32-bit address bus
32/64-bit data bus

4. To trim power and chip cost, designers of the PowerPC 603 from IBM and Motorola reduced the on-chip cache to 16 kbytes and split it into separate 8-kbyte halves, one for data and one for instructions. By splitting the cache, sections can be powered down when not in use, or both sections can be simultaneously accessed to keep performance levels comparable to the 601 chip.

Intel are creating several variants, one of which is rumored to drop into either the 486 socket or the Intel-defined Overdrive upgrade socket. Another variant is a reduced-power version that will incorporate smarter power management or modify some power-hungry sections of the chip to trim overall power consumption by close to 50%.

Trimming the power is key to the Pentium's success. When it was first announced, Intel was pretty confident that the high power consumption of the biCMOS chip—about 12 to 15 W when clocked at 60 to 66 MHz—would be manageable. What Intel discovered, however, was that the 66-MHz chip was hard to fabricate, and many of the smaller system manufacturers weren't well-versed in thermal management and high-speed board design.

Consequently, many early system designs had poor thermal management and clock distribution, causing the CPU to fail or forcing designers to slow down the chip to reduce power. The slower chips, of course, translate into lower system performance. Now many potential users are holding off system purchases until they're sure the system will deliver maximum throughput. Slated for disclosure at next February's International Solid State Circuits Conference in San Francisco, Calif., the "second-generation" Pentium will employ 0.6-μm features, four levels of metal, and achieve 100-MHz internal operation with a power consumption of just 8 W. System manufacturers will find the chip much easier to handle.

In establishing the market for the Pentium, Intel also created a huge market for 386- and 486-class CPUs. To satisfy the demand, yet at the same time differentiate its processors and provide various price and performance points, Intel is pressing ahead with both 386 and 486 variants to try and outmaneuver the "unauthorized" sources.

The first major move by Intel was to incorporate the 386SL power-management approaches transparently into all of its i486-family processors. With power management added, the CPU's average active power was trimmed to levels whereby the CPUs could be housed in lower-cost plastic, rather than expensive ceramic packages. Additional variants are expected throughout 1994.

Unfortunately for Intel, market savvy is also a trait of AMD, Cyrix, and TI. They all have started to proliferate the x86 architecture into both highly integrated one- or two-chip sets, or into higher-performance versions that could eventually compete with the Pentium. At last month's Microprocessor Forum Conference hosted by MicroDesign Resources, Sebastopol, Calif., designers from Cyrix de-

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- **Lowest Operating Supply current:**
  35µA (MAX691A/693A)
  200µA (MAX690A/692A)
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  6ns Typ., 10ns Max.*
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  250mA, 1.2Ω (MAX691A)
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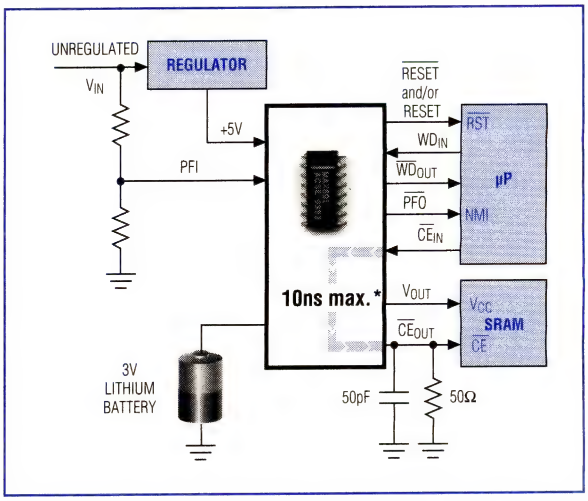
  25Ω (MAX691A)
- **Most Accurate Power Fail:**
  ±2% over temp.
  (MAX800L/M, MAX802L/M)



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Part	Reset Threshold (V)	Power-Fail Comparator	Battery-Backup Switch	Watchdog Timer	Active-High Reset	$\overline{CE}$ Protect	Batt-ON Output	Low-Line Output	ISUPPLY (µA, Typ)
MAX691A	4.65	✓	25Ω	✓	✓	✓/10ns	✓	✓	35
MAX693A	4.40	✓	25Ω	✓	✓	✓/10ns	✓	✓	35
MAX690A	4.65	✓	400Ω	✓					200
MAX692A	4.40	✓	400Ω	✓					200
MAX800L	4.65	✓/±2% accuracy	25Ω	✓	✓	✓/10ns	✓	✓	35
MAX800M	4.40	✓/±2% accuracy	25Ω	✓	✓	✓/10ns	✓	✓	35
MAX802L	4.65	✓/±2% accuracy	400Ω	✓					200
MAX802M	4.40	✓/±2% accuracy	400Ω	✓					200

* *Tested with 50Ω driver and 50pF load. Some competitors misrepresent this specification by not stating test conditions.*

†*Compared with industry Standard MAX691.*

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CIRCLE 195 FOR U.S. RESPONSE **CIRCLE 196 FOR RESPONSE OUTSIDE THE U.S.**

scribed their planned M-1 superscalar enhanced CPU. The device, which is an upgrade to its 486-compatible CPU, will give the Pentium some performance competition.

Earlier this year, Cyrix also released CPUs compatible with Intel's 486DX and 486DX2 microprocessors. The Cyrix chips include both the integer and floating-point units, 8 kbytes of write-back (rather than write-through) cache, and a 16-bit integer multiplier. Combined, these chips form a superset of Intel's 486DX-family processors. Prior to this release, the Cx486 versions sold by Cyrix contained less on-chip cache and required an off-chip math coprocessor to provide all functions of Intel's 486DX-type processors. However, as in its previous CPUs, the Cx486DX and DX2 retain the 16-bit multiplier to improve integer computations typically encountered in signal processing and graphics.

TI, which has a license for some of the Cyrix processors and access to various Intel patents, also created its own 486 variant family, the Potomac series. The chips are 486SLC- and 486SX-compatible, but they contain an on-chip clock doubler. As a result, they can internally operate at up to 50 MHz with a 5-V supply, and to 40 MHz with a 3.3-V supply. The TI486SXLC2 includes an 8-kbyte level-1 cache as well as power-management logic, but employs a 16-bit data bus to the outside world so that it can squeeze into a 100-lead plastic quad-sided flat package. Thus, the circuit can be used in small-format systems such as subnotebook and palmtop computers or PDAs. A version with the full 486SX pinout, the TI486SXL2, includes a full 32-bit data bus and all of the SXLC2's other features.

MARKET SIZE COUNTS

In sheer size, the x86 market, driven by the personal computer, dwarfs every other processor by an order of magnitude or more. This year alone, there will probably be combined sales of over 25 million 386, 486, and Pentium systems. In the world of Motorola 680x0 CPUs, however, only about 5 million CPUs are sold into the Apple Macintosh and other desktop systems (not including peripherals like laser printers). In all likelihood, even with the pending release of the M68060 in early 1994, the number of 680x0-family chips sold won't jump up by a factor of 10.

Motorola, though, has had considerable success with its industrial variants—the 68EC0x0 series and the 683xx family—which are optimized for embedded and vertical market applications. As mentioned earlier, Intel took note of this 32-bit embedded market, releasing details of its 386EX embedded processor.

Remnants of other CISC processors still exist, but with some significant modifications that suit them for embedded designs. The original NS32000 processor family, which was initially crafted as an alternative to the 68000 for desktop computers, underwent a total redesign and reorientation. Now the few available members bear little resemblance to the originals. The new implementations combine the basic CPU with digital-signal-processing (DSP) blocks. That positions the CPUs as controllers for telephone-answering systems and fax/modem cards. Because the cir-

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CIRCLE 553

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CIRCLE 575

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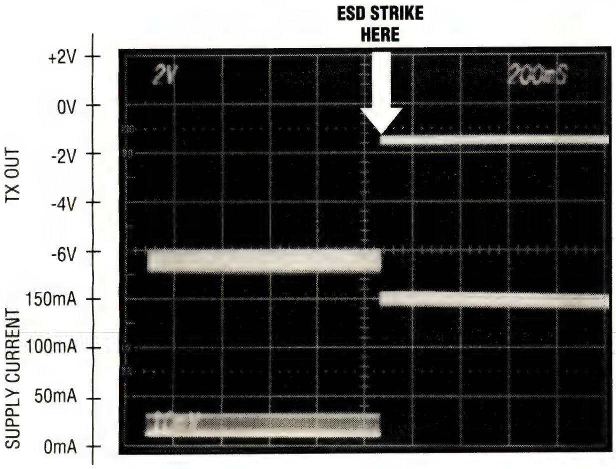
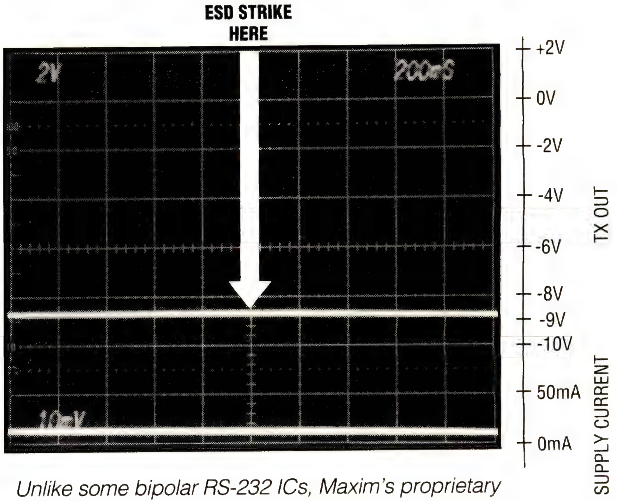


Bipolar Charge Pump Output can collapse, and supply current can increase to 150mA when the receiver input is zapped with -2kV to -10kV, latching the device.

MAXIM CMOS SURVIVES ±10kV ESD



Unlike some bipolar RS-232 ICs, Maxim's proprietary CMOS ESD structure protects RS-232 I/O pins from ±10kV ESD without latching up.

Select a Maxim Latch Up Free, ±10kV ESD, RS-232 IC

Part	TX/RX	ESD**	Caps µF	Latch Up Free	Data Rate kbps	RX Active	Icc (Shutdown)	Price†
MAX211E	4/5	±10kV	0.1	Yes	120		1µA	$3.62
MAX213E	4/5	±10kV	0.1	Yes	120	2	15µA	$3.62
MAX241E	4/5	±10kV	1.0	Yes	120		1µA	$3.62

**ESD testing done on all RX in and TX out pins using Human Body Model waveform detailed in Mil Standard 883 method 3015.7

†1000 up, suggested resale FOB USA.

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CIRCLE 197 FOR U.S. RESPONSE
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cuits have a sophisticated processor on-board, they can handle a real-time operating system that lets them perform multitasking, and can change their functions on-the-fly.

In the RISC world, many CPU choices exist for both desktop/portable systems and embedded applications. The workstation arena started with the M68000 family. But by the early 1980s, the transition over to RISC-based processors had begun, with designers enticed by the higher-integer throughputs as well as very-high floating-point throughputs (compared to 68881/82-type floating-point coprocessors).

The advent of Sun Microsystem's scalable processor architecture (Sparc) opened the doors to a wide selection of Sparc processors that start with simple load-store architectures, such as the original Sparc CPUs from Fujitsu and Cypress Semiconductor. And complexities have now increased to 76 SPECint92, 98 SPECfp92 superscalar architectures like the 60-MHz biCMOS SuperSPARC offered by TI (Cypress sold its Ross Technologies Sparc group to Fujitsu in early 1993). Next year, Sun Microsystems expects to sample the SuperSPARC+, an enhanced superscalar processor with approximately a 50% improvement in throughput.

Around the time Sun Microsystems released the Sparc processor, MIPS Inc. (now the MIPS Technology Div. of Silicon Graphics) introduced the R2000 RISC processors. The Rx000 family has mushroomed into three commercial processor families—the R2000, which is no longer promoted for new designs; the higher-performance R3000 series; and the current high-end R4x00 family. Like Sun Microsystems, MIPS actively lined up silicon licensees that would actually offer commercial CPUs while concentrating on developing and selling the systems.

The R4x000 family features four separate processors: the R4000, R4200, R4400 and the just-released R4600. The R4000 and 4400 are aimed at desktop uniprocessor and multiprocessor systems and have SPECmark ratings of up to 94 SPECint92 and 105 SPECfp92. The R4200 and R4600 were optimized for low-power systems and have slightly lower throughputs, with the R4200 claiming 55 SPECint92 and 30 SPECfp92, while the R4600 delivers 64.5 SPECint92 and about 66 SPECfp92.

One major difference between Suns's and MIPS' families involves the approaches that were taken. Sun Microsystems defined the CPU's instruction-set architecture but let each licensee decide how to actually implement the pro-

TABLE 2: GENERAL-PURPOSE 32-BIT AND LARGER PROCESSOR FAMILIES

(Ranked roughly by the highest-throughput member of the family)

RISC processors

Alpha 2106x family	Created by Digital Equipment (DEC); sourced by DEC and Mitsubishi
PA-RISC	Created by Hewlett-Packard (HP); sourced by HP, Mitsubishi and Samsung
PowerPC 60x	Created by IBM, Apple and Motorola; sourced by IBM and Motorola
M88110	Created by Motorola; sourced by Motorola
Sparc*	Created by Sun Microsystems; sourced by Sun as well as Fujitsu, LSI Logic, Texas Instruments, and Weitek
i860 family**	Created by Intel; sourced by Intel
R4000 family	Created by MIPS Technologies; sourced by IDT, NEC, Performance Semiconductor, Siemens, and Toshiba
R3000 family	Created by MIPS Technologies; sourced by IDT, LSI Logic, NEC, Performance Semiconductor, Siemens, Sony, and Toshiba
Hobbit family	Created by AT&T Microelectronics; sourced by AT&T

* Includes original Sparc processor, the microSPARC series, the SuperSparc series, hyperSparc, UltraSparc, and double-clocked Sparc.

** Although general purpose, the i860 is predominantly found in embedded applications.

CISC processors

Pentium	Created by Intel; sourced by Intel
M-1*	Created by Cyrix; sourced by Cyrix +
M68060*	Created by Motorola; sourced by Motorola
Blue Lightning	Created by IBM; sourced by IBM
TI486 family	Created by Texas Instruments; sourced by TI
Cx486 family	Created by Cyrix; sourced by Cyrix
Am486 family	Created by Advanced Micro Devices; sourced by AMD
486SLC	Created by IBM; sourced by IBM
M68040	Created by Motorola; sourced by Motorola
Am386 family	Created by Advanced Micro Devices, sourced by AMD
Cx386 family	Created by Cyrix; sourced by Cyrix and TI
386SLC family	Created by IBM; sourced by IBM
i386 family	Created by Intel; sourced by Intel (with unlicensed chips from AMD, Cyrix, and TI providing pin-for-pin replacements and speed upgrades)
M68030	Created by Motorola; sourced by Motorola

Highly-integrated 32-bit CISC processors

ELAN	Created by Advanced Micro Devices; sourced by AMD
Polar chip set	Created by Intel and VLSI Technology; sourced by VLSI Technology
80386EX*	Created by Intel; sourced by Intel

* Architecture unveiled but not yet in production.

+ Cyrix uses several foundries to manufacture the chips it sells, such as SGS-Thomson, TI, and others. Some of those foundries also have rights to sell the chips—TI is already selling some, and others are expected from SGS-Thomson.

This is not an all-inclusive listing, but it represents most known products.

cessor to achieve the desired performance level. MIPS, on the other hand, defines the CPU down to the net list and lets each licensee manufacture the processor using their own processes. In either case, each licensee is also free to develop spin-off products to tackle specific markets.

The move to RISC for workstations also stimulated Motorola in the mid-1980s to create the M88000 family. Its progeny, the 88110, is used by Data General Corp. in servers and workstations, and in other forms as an embedded controller for automotive applications. The most exciting offshoot, though, is the incorporation of several aspects of the architecture into the PowerPC processor family jointly defined by Apple Computer, IBM, and Motorola.

MULTILATERAL AGREEMENT

Currently, the trio of companies has defined four chips in the first generation, the PowerPC 601, 603, 604, and 620. The first three implement a 32-bit subset of the 64-bit PowerPC architecture. The 601 CPU is targeted at mid-range desktop systems, uses a 64-bit data bus and 32-bit address bus, and delivers a throughput of over 62 SPECint92 and 72 SPECfp92 when running at 66.7 MHz. A higher-speed version of the 601 that runs at 80 MHz was just released for sampling. That higher-speed option ups the 601's throughput by close to 20%.

Aimed at portable systems and entry-level desktop computers, the PowerPC 603 employs more on-chip power management and a smaller on-chip cache (16 kbytes versus 32 kbytes), but can run at up to 80 MHz thanks to a triple-metal, 0.5-μm CMOS process used to fabricate the chip *(Fig. 4)*. Both IBM and Motorola will sell the processor. At that top speed, the 603 will deliver throughputs of 75 SPECint92 and 85 SPECfp92 (ELECTRONIC DESIGN, *Nov. 1, p. 35)*.

Most details of the 604 have yet to be unveiled, but it will take aim at higher-performance desktops and servers, and it will employ a 64-bit data bus. The top-of-the-line 620, which implements the full 64-bit PowerPC architecture, will probably be sampled in late 1994.

At the high-end of IBM's product offerings are the Power1 and the just-released Power2 chip sets, which the company uses for the RS/6000 workstations. Although they're not commercially available, the chip sets show what can be done to push performance. The Power2 chip set will come preassembled in a multichip module to ensure top performance—126 SPECint92 and 260 SPECfp92 when clocked at 71.5 MHz. The Power2, a superscalar architecture, carries over some of the architecture tricks used by the Power1 processor to deliver its 73 SPECint92 and 124 SPECfp92 throughput at 62.5 MHz. Common traits include register rename and decoupled execution units. Added to the Power2's repertoire were out-of-order instruction execution and a virtual multiported cache.

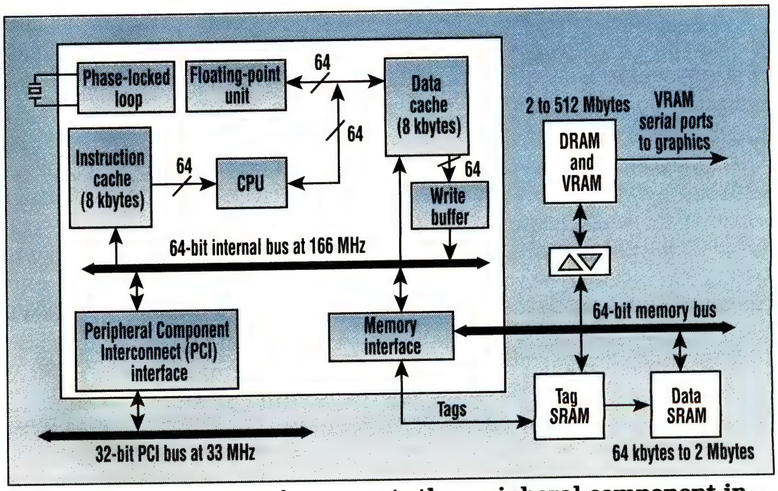
Prior to the introduction of the Power2-based systems, DEC held the speed lead with its 200-MHz Alpha 21064 processor. It delivers a throughput of 116 SPECint92 and 193 SPECfp92, albeit with a power dissipation of about 25 W. Although momentarily passed in performance by the Power2, DEC has recovered the performance lead with an enhanced version of the 21064—the 21064A. Unveiled last month, the new chip has a top clock speed of 275 MHz and ups the throughput to 175 SPECint92 and almost 300 SPECfp92.

Part of that performance gain is due to the process, but the rest of the gain comes from circuit enhancements—caches were doubled in size to 16 kbytes each, the on-chip divider efficiency was doubled, and it incorporates an improved branch-prediction scheme. Power drain, though, thanks to the 0.5 μm, four-layer metal process, stays at about 25 W.

DEC solved the problem with a pair of new, highly integrated Alpha processors, one geared for entry and mid-range desktops—the 21066—and the other for embedded systems—the 21068 (ELECTRONIC DESIGN, *Oct. 14, p. 138)*. Both are actually the same chip, with the 21068 rated for just 66 MHz, maximum, while the 21066 runs at up to 166 MHz and delivers 70 SPECint92 and 105 SPECfp92.

The 21066 is the industry's first RISC or CISC processor to integrate the peripheral-component-interconnect (PCI) expansion bus, reducing the off-chip parts count when building a system motherboard *(Fig. 5)*. To cut both chip cost and power, designers at DEC lowered the data bus from 128 bits on the 21064 down to 64 bits on the 21066 and 21068, trimmed back the cache by 50% to 16 kbytes, and applied a 0.68-μm, triple-metal CMOS process.

Although a few PA-RISC chips are being sold to other



5. The first processor to incorporate the peripheral-component-interconnect (PCI) bus, the 21066/68 Alpha processor developed by Digital Equipment Corp., provides a simple system solution for designers of both desktop or embedded systems. To reduce the cost versus the original 21064 Alpha processor, the 21066/68 use a 64-bit data bus rather than a 128-bit-wide bus, reducing pin count and package cost.

companies, HP has kept its processor family pretty close to home, using it in the 700-series workstations. With a throughput of 80 SPECint92 and 150 SPECfp92, the 99-MHz PA7100 delivers better integer and floating-point performance than SuperSPARC-, Pentium-, PowerPC 601-, and Power1-based systems. It also has slightly lower integer performance but better floating-point performance than R4400-based systems, and 20-40% lower performance than Alpha- or Power2-based systems. HP also plans to unveil another iteration of its processor at ISSCC: The clock will cranked up to 146 MHz, which is a 50% speed boost (and probably close to a 50% boost in throughput).

RISC for embedded applications has become quite popular due to the RISC cores' high throughputs. Furthermore, the applications often don't depend on existing software—the systems need not run thousands of commercial application software packages. Thus, designers are more at ease in selecting a processor that best suits the task rather than force-fitting a CPU that must run previous software.

Because there's little software "baggage," designers can select among a number of RISC processors in addition to the older CISC architectures. These include AMD's Am29000, ARM's Acorn engine from VLSI Technology and others, the transputers from the Inmos Div. of SGS-Thomson, and the i960 and i860 processors from Intel. There's also the 88110 from Motorola; various Sparc offerings from Fujitsu; several R3000 and R4000 CPUs from IDT, LSI Logic, Toshiba and others; and most recently, V800 series from NEC and the SH 7000 family from Hitachi.

Although not well established in the U.S., the Inmos transputer family has made some strong inroads into embedded control across Europe. The latest member, the T9000, offers designers a high-performance integer processor that executes 200 MIPS and a floating-point coprocessor that delivers 25 MFLOPS. The transputer can be used in multiprocessor arrays thanks to its four 100-Mbit/s serial link ports for interconnecting processors. The chip is now being sampled.

The second-generation of Hitachi's SH processors, the SH-II series, was previewed at last month's Microprocessor Forum. Optimized for multi-chip system implementations, the new family is more performance optimized than the SH-I family. If run at 28.5 MHz with external synchronous DRAMs, a 5-V SH-II CPU will deliver about 25 MIPS. The SH-I family is targeted at single-chip solutions, which are needed in PDAs that have integrated RAM, ROM, DSP and I/O functions. On one chip sits the 32-bit CPU with a 16-bit 3-cycle integer multiplier and a 16-bit external data path, 4 or 8 kbytes of RAM, 64 kbytes of ROM or EPROM, and four DMA channels. The chip also contains two serial ports, a 16-bit integrated timer/pulse unit, an eight-channel 10-bit analog-to-digital converter, and an interrupt controller.

When run at 20 MHz, the SH-I processors achieve 16 MIPS (at 1 W), which is 5 to 10 times lower than most other RISC chips, except perhaps for the Hobbit processor from AT&T Microelectronics (ELECTRONIC DESIGN, *Nov. 1, p. 101)*. The Hobbit family, though, is targeted specifically at the personal communicator/PDA market.

Expected to be a direct competitor, at least in Japan, NEC's V800 family of low-power RISC engines is targeted at many of the same applications as the SH family. The family initially includes two CPUs—the V805 and 810. A third, the V820, is now in design. They will all employ a CPU core that possesses a simple 5-stage pipeline, 16/32-bit instructions, and a 1-kbyte instruction cache for a total of just 240,000 transistors and a power drain of 500 mW when run at 5 V and 25 MHz. The 805 has a 16-bit external data bus and a 32-bit address bus; the 810 has full 32-bit address and data buses; and the forthcoming 820 will include the 810 as a core and add many on-chip peripheral functions. The process used to implement the processors allows operation over a 2.2-to-5.5-V range, although at 2.2 V, the top speed reduces to about 10 MHz.

Licensees of HP's PA-RISC architecture—Oki Electric Co. Ltd. (Oki Semiconductor in the U.S.) and Hitachi—also developed versions of the PA-RISC architecture targeted at embedded control and portable workstation applications. Both companies detailed their architectures at last month's Microprocessor Forum conference. Neither, though, indicated whether they plan to market the processors in the U.S.

Highly integrated RISC chips are gaining popularity for embedded applications, with the Hitachi and AT&T offerings only two of over half-a-dozen choices. Earlier this year, VLSI Technology (in cooperation with Advanced RISC Machines), AMD, IDT, LSI Logic, and others began offering CPUs with a variety of system support functions. The ARM 6 processor jointly defined Apple, ARM, and VLSI has found its way into Apple's Newton PDA system, serving as the heart of the system along with a custom chip Apple developed to round out the internal resources.

Its next-generation offering, the ARM7 series, was unveiled last month by Advanced RISC Machines. When fabricated in a 0.8-μm, CMOS, 2-layer metal process, the core requires just 35,610 transistors and occupies just 5.9 mm^2. That small area suits the CPU well as a macrocell for use in a custom comtrol circuit. The first standard CPU built around the core is the ARM700, which packs an 8-kbyte cache (4-way set-associative), a memory management unit, an 8-word write buffer, and test support. When powered by a 5-V supply, the ARM700 can deliver a throughput of over 53,000 Dhrystones (version 2.1) at 33 MHz and over 31,000 Dhrystones at 3 V and 20 MHz.

The Am29000 family has already found homes in laser printers, network bridges and routers, and many other embedded applications. It new cousin, the four-chip Am2924x series, is a high-integration branch of AMD's popular 29000 family. The 29240, 242, 243, and 245 include such features as a 32-bit processor core with a 32-by-32-bit multiplier, 4 kbytes of instruction cache, 2 kbytes of data cache, and a small memory-management unit. Other features include four-channel DMA, DRAM, and interrupt controllers; parallel and dual serial ports; a specialized high-speed serializer/deserializer; and timer-counters. Not all features are on every chip. ED

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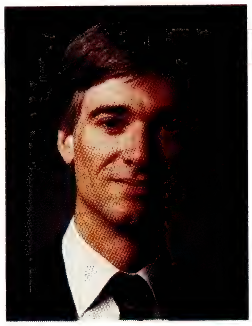

K.C. Murphy

Vice president of corporate strategic marketing and applications, Advanced Micro Devices Inc.

As TECHNOLOGY progresses, we see computing and communication devices taking on new form factors more suited for modern, mobile lifestyles. This transformation is similar to the stereo's evolution from a cabinet-sized unit to the portable Walkman. Today, the transformation is occurring in personal computers. Just as technological changes freed music lovers to listen to their tunes any time or any place, ongoing enhancements in size, power, and ease-of-use have resulted in palm-sized computing and communicating devices that adapt to how users prefer to work.

In today's marketplace, three major mobile computing categories have emerged. First is the standard, 8.5-by-11-in. notebook computer, which now challenges larger systems as a desktop replacement. The second category is the subnotebook, which is used mostly as a mobile companion system. The last major category consists of personal information devices (PIDs), which are defined as application-specific, communications-centric consumer devices.

This nascent mobile market is already the fastest growing segment of the PC industry. Through innovations in operating systems and applications, the ease-of-use barriers are disappearing, making the systems more appealing to a wider range of users. Individuals are finding it easier to integrate mobile computers into their lives as these devices become truly personal.

The mobile worker ranges from the power user to the non-technical person. For example, there are those professionals who take their data and processing capabilities on the road to facilitate their jobs. These users exemplify trends seen in the industry, such as the dissolution of the centralized office and the need for direct information access in a highly competitive, global marketplace. Mobile computers also are increasingly used in vertical applications, assisting in such tasks as managing inventory in warehouses, tracking shipped packages, and even checking in a rental car at the airport.

In the past, systems vendors mixed and matched feature sets in desktop models, competing through product differentiation and distribution channels. But the increasing need for small chip counts to save space, system power management to maximize battery life, and limited add-on capability in mobile computers will enable semiconductor firms to define many of the future features and functions.

As logic-technology size shrinks, semiconductor manufacturers are more able to design products that combine increased feature sets into one chip. Today, this technology has led to the development of many highly integrated chips that combine a variety of communications and peripheral logic into one component. One example is AMD's recently announced full-featured "computer-on-a-chip," the industry's first such device. Code-named Elan, the chip has a 80386 core combined with standard chip-set logic, power management, and a PCMCIA interface. It may also be customized to differentiate products for OEMs. In addition, with the migration to 3.3 V, as is the case with AMD's Am386SXLV for the HP OmniBook 300, interface and partitioning decisions can be better made prior to integration.

Even tighter integration of logic and increased combined functionality will be coming as technologies dwindle down to 0.4 and 0.35 μm in the next several years. For example, new features such as voice recognition and pen interfaces will quickly be integrated into silicon solutions. Therefore, semiconductor companies who provide telephony and audio digital signal processing can further advance the speed and accuracy of these input technologies.

Flash-memory technology also provides a significant opportunity for semiconductor manufacturers. Although rotating devices will continue to be the most cost-effective storage for needs above 60 Mbytes, the speed, low-power consumption, ruggedness, and small form factor advantages of flash make it ideal for PIDs and subnotebooks. In the near future, flash components like AMD's 29F010, the industry's first 5-V-only device, will store much of the operating system, offering users improved system performance and instant-on capability (the ability to start a system at the same point it was shut down). In addition, software manufacturers may some day be able to quickly and easily distribute updated software stored in flash products to mobile users, perhaps over telephone lines.

The most important need in these mobile systems is communications capabilities. Wireless WAN communications technology will develop as key alliances build between hardware and infrastructure providers. However, today, wire hookups are more readily available in LAN situations, and applications needing wireless LAN access are still developing. Therefore, wireless LANs will evolve later as an extension of standardized WAN capabilities.

The emergence of the mobile computing market has opened new, uncharted territory for the personal computer industry. By 1996, it's expected to reach over $14 billion, and by 1997, it will account for almost 50% of the overall computer market. This explosive growth gives semiconductor and systems manufacturers the opportunity to dominate a new multi-billion dollar market through differentiation and innovation. In all cases, the winners will be those who develop products that provide value to the end-user market, and service the needs of a more mobile world. ED

THE KEY TO PERSONAL COMMUNICATIONS

FULLY INTEGRATED FACILITIES WILL ASSURE SUCCESS OF PERSONAL COMMUNICATORS

Rob Franzo
Member of the technical staff, AT&T Bell Laboratories

THE SUCCESS OF personal-productivity tools will hinge largely on the integration of their communication facilities, a feature still lacking in the many available handheld and laptop computers. A new class of personal-productivity devices, or "personal communicators," must be developed. The devices should have seamless support for voice, fax, and data information types, as well as messaging ability through various land-line and wireless channels. Personal information managers (PIMs) and note takers must also complement the personal-productivity device's communications focus. However, most vendors of such tools have modeled their systems after desktop computers with add-on communication features.

Designers and manufacturers must understand who the end user is—a mobile worker who may be getting by with a cellular telephone that requires more robust communications capabilities. What's needed is a telephone extension that offers voice, data, and fax messaging, and provides access to emerging store-and-forward messaging networks so that important communications aren't lost. This is where the personal communicator steps in. In fact, it also provides note-taking and PIM facilities needed by mobile workers.

Technical obstacles to building a low-cost personal communicator are caving in. For example, the still-high prices of LCD panels have started to tumble while display quality is improving. Such changes in key component areas are driven by synergistic consumer markets, including notebook computers and cellular telephones. Portable products have forced battery designers to innovate storage cells with extended life. But these battery-life improvements are still modest and require portable-equipment designers to focus on low-power design methodologies.

Power concerns require personal-communicator designers to employ a compute engine and operating system that differs from the standard microprocessor, support chips, and software used in PCs. What's needed are a low-power core design, a power-saving processor architecture that minimizes system power consumption, and advanced power-management facilities to save the batteries during periods of inactivity. The operating system must be capable of active power management, yet support low-latency multitasking to manage real-time communication channels.

Silicon technology, like AT&T's 92K Hobbit family of 3.3-V processors, is now available to match these goals. They include low-power and even no-power modes and use a C-optimized architecture that minimizes the number of accesses the processor must make to power-hungry external memory. The family also includes complete system designs that range from a two-chip set that can be used in cellular-phone-size personal communicators to a five-chip set that offers enhanced I/O and video options. The PenPoint operating system that was ported to the Hobbit processor offers multitasking, power management, and support for intuitive pen- and voice-based user interfaces.

The portable nature of personal communicators mandates support of wireless communication channels as well as traditional land-line links. Wireless networks, in fact, are the key to the market success of personal communicators. In developing communication support for a personal communicator, a designer can choose from many wireless options, including Groupe Speciale Mobile (GSM) and Advanced Mobile Phone System (AMPS). Soon to be layered upon the AMPS network are either cellular-digital-packet-data (CDPD) or dual-mode IS-54 networks. In addition, Mobitex and Advanced Radio Information Services (ARDIS) radio packet networks are available. Cellular networks are a suitable link for voice messages, and for the transfer of faxes or large amounts of information via cellular modems. But these circuit-switched connections cost more than users are willing to pay for short electronic messages. Radio packet networks may be more cost-effective.

Different communications options use incompatible transmission techniques and different data-transfer protocols. Thus, designers who use fixed-function communication interfaces will have to concentrate on one type of wireless network, or offer support for different networks optionally as add-on capabilities to the base design.

Designers working with Hobbit, however, can also take advantage of AT&T's reprogrammable DSP technology to integrate support for different networks directly in the personal communicator. The designer can integrate a DSP on the motherboard and implement support for the different networks via software and modular RF interfaces.

Presently, different information and messaging services use incompatible means of access. To make personal communicators as easy to use as a telephone, designers must integrate direct support for services and use the menu-driven interface of a personal communicator to hide communication details from the user.

Hobbit-based personal communicators already feature integrated support for some services, such as voice mail. Direct integration for other services will evolve, accelerated by two factors. First, the adoption of high-level communication protocols, such as Telescript designed by General Magic, will cause the different services to gradually adopt compatible interfaces. Second, services will blend their offerings through gateways, ultimately allowing anyone that can make a long-distance call to have access to all services. As a result, unified messaging is possible. ED

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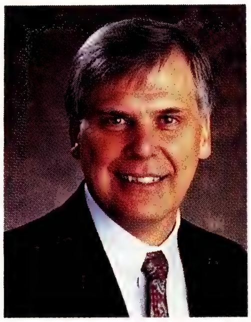

Jerry Rogers
President and CEO, Cyrix Corp.

WE'RE CONFIDENT THAT the x86 microprocessors will remain the architecture of choice and continue to dominate the industry. One reason for such confidence is that the x86 fills the needs of a wide performance spectrum. At one end, it meets the challenges of the power user. At the other end, it satisfies the integration requirements of new computing technologies, such as personal digital assistants. This kind of breadth makes renders other types of microprocessors unnecessary.

In fact, market figures attest to this. For example, CPU makers are expected to ship 40 million x86 microprocessors this year, while 500,000 units of all other CPU architectures are projected for this year. In addition, industry estimates that those 40 million x86s will total $8 billion in sales.

There are three fundamental reasons for such faith in the continuing success of the x86 family. First, the architecture is based on a standard that has captured the hearts and minds of computer users. Second, the x86 architecture can accommodate the high level of integration needed for new technologies like multimedia. And finally, x86-based PCs possess the essential features that users demand.

Software and hardware based on the x86 architecture are pervasive, with x86-based systems growing at a rate beyond the wildest imagination of industry pundits. The momentum of the market and its technology can't be redirected considering the amount of research and development that's invested in this architecture, the talent working on its continued improvement, and the choices of PCs and software afforded to the consumer.

Industry proponents of alternative architectures believe that the demise of the x86 will occur when the market demands for the integration of multimedia and other new technologies aren't met by the x86's architecture. While it's true that the x86 currently isn't handling these functions adequately, the hardware can adapt to emerging markets requiring high levels of integration.

Today, multimedia is added to the PC with the combination of an add-on board and software. The board plugs into the AT, EISA, or MicroChannel add-on bus slot. Software is installed to run the applications, as well as handle communications between the Windows/DOS operating system and the hardware/software multimedia application. There are hardware/software combinations for virtually any multimedia application, including sound, video, speech, fax, and modem.

Microprocessor vendors are looking to combine multimedia functions with a popular microprocessor, such as the x86. For example, combining digital signal processing and an x86 microprocessor into one chip appears to eradicate a great deal of hardware. DSP functionality on the motherboard would eliminate the need for an add-on board or additional hardware to run multimedia applications. Also, the combined digital signal processor and microprocessor would facilitate the integration of various applications, including video and sound; speech synthesis and recognition; fax modem and text recognition; and fax modem to speech output.

But this approach does create a number of problems. First, there's the dilemma of which operating system to use. Furthermore, users would need a high-level language for software development, because no development systems are currently available to handle this combined-processor approach.

The inability to deal with problem issues has led design teams to explore non-x86 multimedia solutions. Neither the i486 nor the Pentium appear suitable for digital signal processing. However, the x86 can be modified to accommodate DSP functions, as well as execute all of the existing Windows software. There's no reason why the x86 can't be designed with numeric performance comparable to that of today's leading digital signal processors. In addition, an x86-based digital signal processor would be one-tenth the size of a Pentium microprocessor, yet it would provide ten times the performance.

There are numerous advantages to an x86-based digital signal processor. First, over 100,000 hardware and software engineers around the world understand the x86, and how to design and develop x86 hardware and software applications. There are x86 compilers for all of the high-level languages used in application development. And because algorithms for DSP functions typically are developed on an x86 and then transported to the native digital signal processor, a vast majority of the DSP algorithms already exist on the x86. Furthermore, debuggers for quick and efficient development of applications are available, along with the development systems that are unavailable for existing digital signal processors and RISC processors.

Last, and most important to the end user, is the plethora of hardware and software choices based on the x86. For instance, x86 users won't cast aside a significant investment already made in software, and a wide array of new software. In addition, the x86 provides the performance level that's currently required by the end user, and is quickly moving up the performance ladder as the requirements increase. Although the manufacturer must be concerned with performance, they must also address the price sensitivity of the consumer. The proliferation of choices has led the end user to demand that performance be coupled with value. ED

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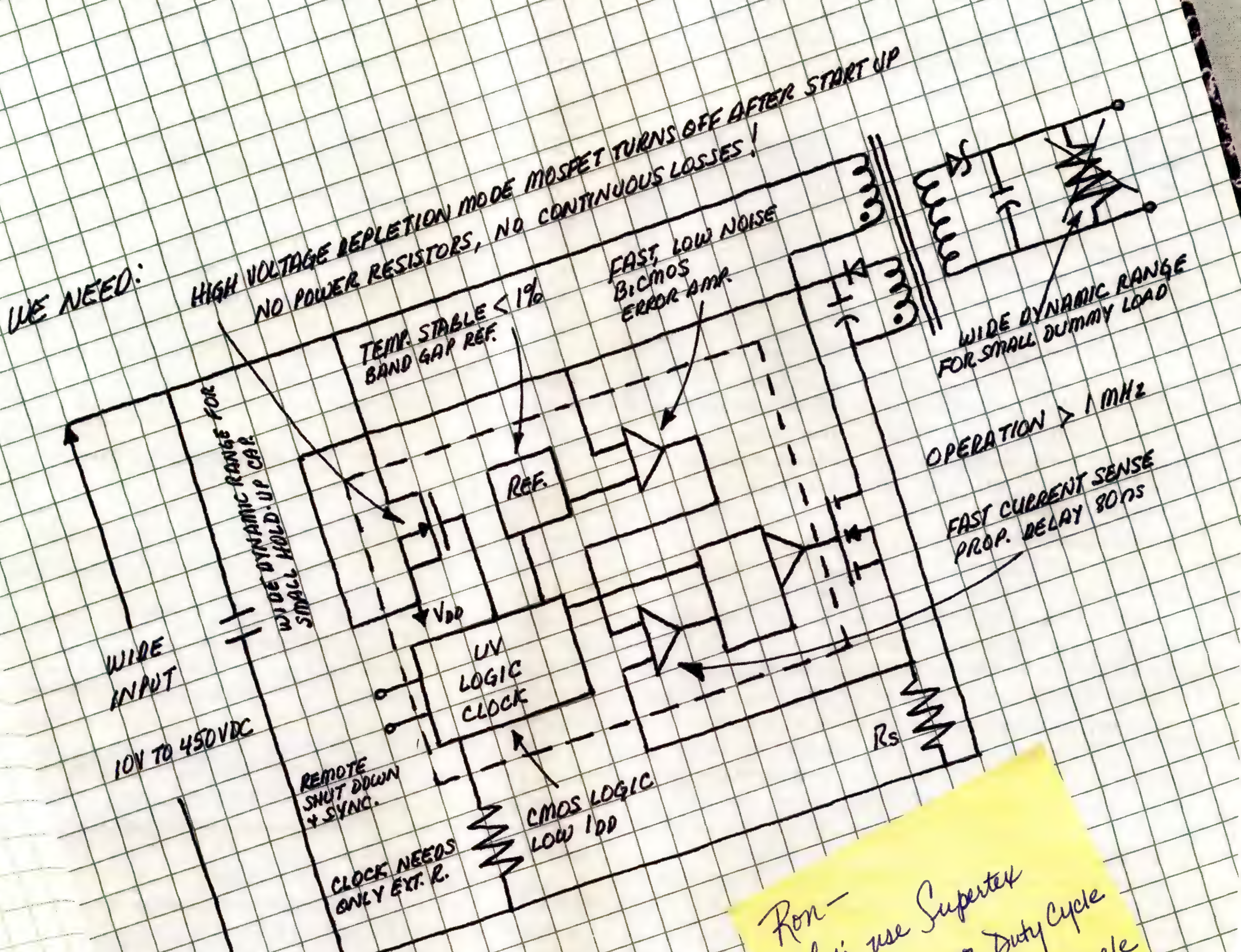
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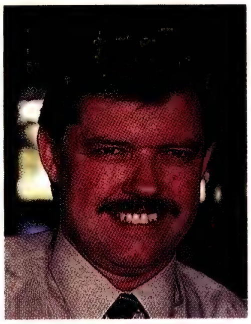
THE FUTURE OF PERSONAL COMPUTING

DIGITAL SIGNAL PROCESSING FUELS CHANGES AS THE MULTIMEDIA ERA NEARS



Garth Hillman
PC media manager, Digital Signal Processing Div., Motorola Inc.

PERSONAL - COMPUTER manufacturers struggle daily to differentiate their machines as prices drop off precipitously, competition increases, and profit margins shrink. This coming year, however, will signal a significant turning point in the PC market as a number of the major manufacturers differentiate their machines with multimedia functionality that was only dreamed of in the very recent past. Multimedia functions come from three different disciplines: communications, entertainment, and computing. The enabling technology driving this revolution is digital signal processing (DSP).

Traditionally, DSP ICs have fueled the communications, audio, and voice-processing markets. But at their current price/performance level, PC manufacturers also are finding them acceptable. DSP technology allows the transformation of PCs into personal communication centers. Under software control, a single, general-purpose DSP IC can function as a modem, audio processor, voice-compression engine, telephone answering machine, and much more.

No longer will users be required to buy expensive add-in cards for each function or use valuable component space in their machines. PC manufacturers can use general-purpose, programmable DSP ICs to expand on this functionality by simply adding software, further differentiating their products. These flexible processors will replace today's fax and modem chip sets and provide a stepping stone from 14.4k-bit/s document and data transmission to the 28.8k-bit/s V.fast standard of the near future. Sophisticated telephony features can be implemented using the same hardware, significantly reducing the cost per function.

These functions include dial-tone generation; call-progress monitoring for phone-line control; and standard phone-answering-machine functions—record and playback, fast forward, and reverse. Calls can be placed and received by double clicking on a graphical user interface (GUI), and delivered on a full-duplex speakerphone with electrical and acoustic echo cancellation.

Unanswered incoming calls can be recorded on a tapeless answering machine that uses a complex speech-compression algorithm. Raw voice storage requires one megabyte per minute, but the powerful compression techniques of DSP allow for the support of standard voice-compression technologies like DVI-ADPCM, MS-ADPCM, and VSELP, which conserve valuable hard-disk storage space with compression ratios of up to 32:1. Time-harmonic scaling algorithms will allow calls to be played back at a faster or slower rate with no change in the pitch of the voice. All of these functions, and more, can be accomplished using a single sophisticated DSP ICs like Motorola's DSP56002.

The tremendous calculating power of DSP ICs enables them to perform these communications functions at blazing speeds without burdening the host. Still other functions benefit as well. Voice processing enhances traditional PC applications as well as adding completely new capabilities. For example, speaker verification will secure the PC by responding only to a personal voice print. Voice recognition will allow commands to be spoken rather than pulled down from a menu using a mouse, and oral data input instead of manual typing. DSP ICs cancel acoustical voice echoes to provide higher accuracy as well as a significantly increased vocabulary size. Text-to-speech synthesis enables the user to have print read to him from the screen.

Combined with communications capabilities, text-to-speech functions also can turn a PC into a teleconferencing machine. For example, the user can call in from the field and have facsimiles and electronic mail read aloud over the phone, making PCs even more indispensable.

Other media that benefit from DSP are the education and entertainment markets. The huge library of existing educational and entertainment software will be enhanced by the superior audio-processing capabilities of DSP ICs. Sound effects such as reverberation, 3D sound, and graphic equalization increase output-signal quality. Future generations of computer games will call upon wave-table synthesis to produce sounds. This algorithm produces truer instrument samples than today's synthesized sounds. The processors can support the Musical Instrument Digital Interface (MIDI), which equips PCs for music composition and production by allowing data exchange between electronic instruments and other sound equipment.

In addition, a DSP IC can run real-time sample rate conversion, allowing applications to mix audio information from sources with different sampling rates, such as phones (8 kHz), compact discs (44.1 kHz), and digital audio tape (48 kHz). Digital audio and images consume prodigious amounts of data, and the higher the signal's quality, the higher the data density. Moreover, the powerful processing power of DSP ICs allow them to support MPEG audio-compression and JPEG image-compression standards.

As PC manufacturers embrace new technologies to help differentiate their products and stabilize their plunging prices, DSP will be the enabling technology that brings first-generation multimedia applications to the desktop. Product maturity, increased ease-of-use, and total hardware and software solutions developed by DSP manufacturers will fuel the convergence of computing, communications, and entertainment in the PC market. ED

Co-authored by Leslie Fisher, product marketing, Motorola Inc.

GROUP COMPUTING FACES MANY OBSTACLES

SUCCESS IN COLLABORATIVE COMPUTING RELIES ON NETWORKING STANDARDS

Charlie Carinalli
Senior vice president and chief technical officer, National Semiconductor Corp.

ONE OF THE MOST important and challenging technical issues of the coming decade is the evolution of networking technologies, which is driven by the demand for collaborative workgroup computing. Today's networks and multimedia applications have only begun to scratch the surface of the communications infrastructure needed for effective group computing. Business and technical users want to be able to share work in progress, from spreadsheets and charts to photographs, drawings, complex CAD designs, and video conferences. And they want this capability at their desktop in real time without elaborate hardware additions.

Such collaborative workstyles can save both time and money, but demand high-quality voice and video to communicate effectively. Most of today's networks, however, provide only data capability in packet transfer applications that can't handle video and audio at acceptable quality levels. Collaborative computing implies that the multimedia desktop must extend through the WAN for end-to-end connectivity. Multimedia communication over the WAN must be as easy to use as our telephones and television sets, and it must offer the same quality. Viewing multimedia communications from this perspective, it's clear that different industries—each with its own competencies—will have to work together.

The first solution to these issues was realized through the introduction of isochronous services in both Ethernet LANs and FDDI networks. These developments represent evolutionary steps that allow users to build on installed networks they already use. Isochronous Ethernet, for example, maintains the packet services for normal Ethernet, while adding isochronous services for multimedia communications.

National Semiconductor's isoENET was unanimously accepted by the IEEE 802.9 standards committee in March 1993 as a working standards document. Under this proposal, isoENET offers standard 10-Mbit/s Ethernet data services, but adds 96 B channels of 64 kbits/s each, resulting in a total bandwidth of 6.144 Mbits/s for isochronous communications. Also included is a D channel for signaling and call setup. These data B channels and D channel are separate at both the node (or PC) and the hub—they're combined only on the 10BaseT wiring. Second generation FDDI, known as isoFDDI, is structured in similar fashion to support both standard FDDI and isochronous services.

At present, the future solution centers on the asynchronous transfer mode (ATM), which is a new standard rather than an upgrade of Ethernet or FDDI. While ATM can still be integrated with existing networks to preserve users' investments, an ATM network will provide exponential boosts in productivity. ATM standards are based on telephone standards and can support various operating speeds, from 25 Mbits/s up to gigabits/second.

ATM also promises a single platform for collaborative computing. A typical desktop installation today might include a Macintosh using Appletalk for printer sharing; an Ethernet board and connection to the company LAN; and an IRMA board and connection to communicate with the company's IBM mainframe. The same office may also have a PBX. The problem is that none of these network solutions connect to each other, resulting in lots of excessive hardware (and cost). ATM could provide all of these functions over a single network topology. Its first deployment is expected to be a collaborative computing backbone to hub/routers of isoEthernet like LAN technology.

Software development is another major issue. Most developers of ATM products will find it essential to provide complex software to support products introduced in this market. National Semiconductor, for example, in addition to basic software provided with design boards, will supply sophisticated software (such as signaling and LAN emulation) for its production-ready boards.

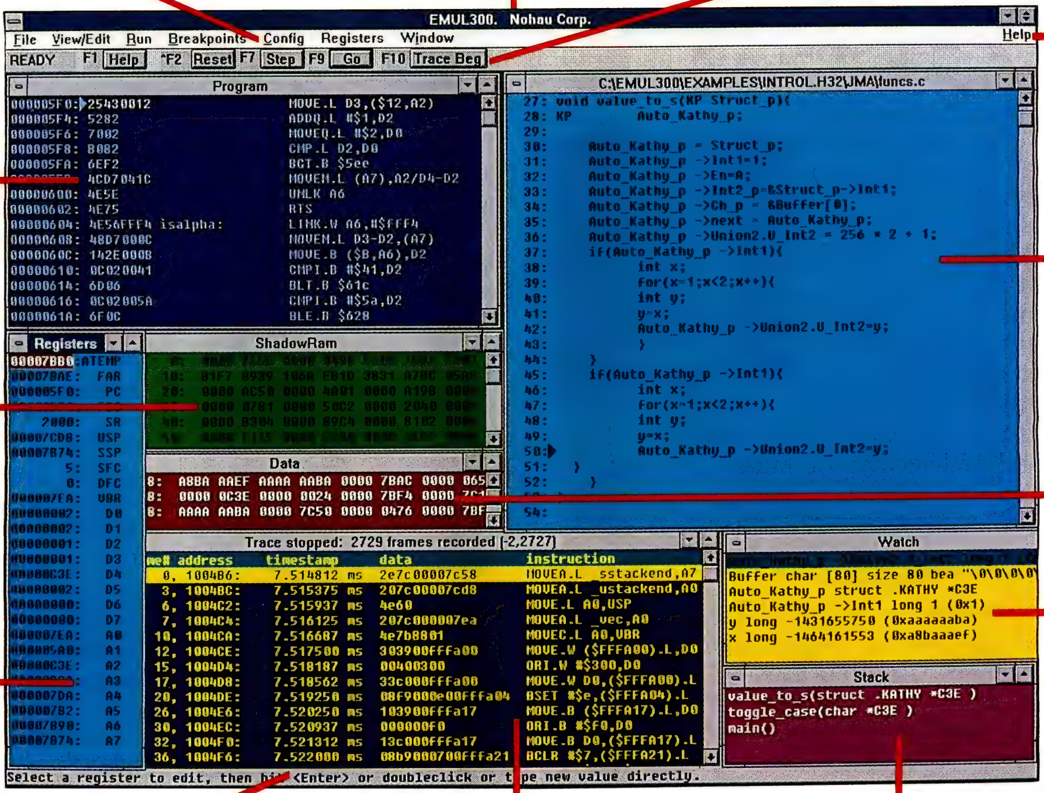
Another challenge facing ATM and other advanced networks is the integration of seamless LAN and WAN connectivity. In addition, interoperability and compatibility must be assured with a number of audio and video compression/decompression technologies, in which software again plays a critical role. Many companies, including National Semiconductor, are working on both hardware and software compression. Proprietary compression schemes will be commonplace, with a default fallback to the CCITT H.261 compression standard for WAN applications.

National's experimental compression method is unique in several ways that are important to the end user. The compression relies on a technique that uses 100 times less computation than the complex mathematical methods used in existing standards. Because the compression scheme requires less computational power, the algorithm can run on a host PC without add-in cards. Moreover, the algorithm supports chalkboard collaboration because it preserves the edges of text or lines captured from the screen or other scanned documents.

All of these advanced networking technologies are crucial to the development of true collaborative computing and inter-workgroup productivity. They're strategic technologies that will directly affect the future of our industry, making new capabilities available for companies planning to re-engineer their networks to achieve exponential productivity gains. ED

In-Circuit Emulators and Background Debuggers

68300 68HC16



```
000005F0:▶25430012                MOVE.L D3,($12,A2)
000005F4: 5282                    ADDQ.L #$1,D2
000005F6: 7002                    MOVEQ.L #$2,D0
000005F8: B082                    CMP.L D2,D0
000005FA: 6EF2                    BGT.B $5ee
          4CD7041C                MOVEM.L (A7),A2/D4-D2
00000600: 4E5E                    UNLK A6
00000602: 4E75                    RTS
00000604: 4E56FFF4 isalpha:       LINK.W A6,#$FFF4
00000608: 48D7000C                MOVEM.L D3-D2,(A7)
0000060C: 142E000B                MOVE.B ($B,A6),D2
00000610: 0C020041                CMPI.B #$41,D2
00000614: 6D06                    BLT.B $61c
00000616: 0C02005A                CMPI.B #$5a,D2
0000061A: 6F0C                    BLE.B $628
```

```
void value_to_s(KP Struct_p){
KP          Auto_Kathy_p;

    Auto_Kathy_p = Struct_p;
    Auto_Kathy_p ->Int1=1;
    Auto_Kathy_p ->En=A;
    Auto_Kathy_p ->Int2_p=&Struct_p->Int1;
    Auto_Kathy_p ->Ch_p = &Buffer[0];
    Auto_Kathy_p ->next = Auto_Kathy_p;
    Auto_Kathy_p ->Union2.U_Int2 = 256 * 2 + 1;
    if(Auto_Kathy_p ->Int1){
          int x;
          for(x=1;x<2;x++){
          int y;
          y=x;
          Auto_Kathy_p ->Union2.U_Int2=y;
          }
    }
    if(Auto_Kathy_p ->Int1){
          int x;
          for(x=1;x<2;x++){
          int y;
          y=x;
▶         Auto_Kathy_p ->Union2.U_Int2=y;
  }
    }
```

```
00007BB6:ATEMP
00007BAE:  FAR
000005F0:   PC
    2000:   SR
00007CD8:  USP
00007B74:  SSP
       5:  SFC
       0:  DFC
000007EA:  VBR
00000002:   D0
00000002:   D1
00000001:   D2
00000001:   D3
00000C3E:   D4
00000002:   D5
00000000:   D6
00000000:   D7
000007EA:   A0
000005A0:   A1
00000C3E:   A2
        :   A3
000007DA:   A4
000007B2:   A5
00007B98:   A6
00007B74:   A7
```

```
10:  B1F7 8939 106A EB1D 3831 A7BC 05A
20:  0000 AC50 0000 4A01 0000 A198 000
     0000 0781 0000 58C2 0000 2040 000
40:  0000 B304 0000 89C4 0000 8102 000
```

```
8:  ABBA AAEF AAAA AABA 0000 7BAC 0000 065
8:  0000 0C3E 0000 0024 0000 7BF4 0000 7C1
8:  AAAA AABA 0000 7C50 0000 0476 0000 7BF
```

```
Trace stopped:  2729 frames recorded [-2,2727]
me# address    timestamp     data              instruction
  0, 1004B6:   7.514812 ms   2e7c00007c58      MOVEA.L  sstackend,A7
  3, 1004BC:   7.515375 ms   207c00007cd8      MOVEA.L _ustackend,A0
  6, 1004C2:   7.515937 ms   4e60              MOVE.L A0,USP
  7, 1004C4:   7.516125 ms   207c000007ea      MOVEA.L _vec,A0
 10, 1004CA:   7.516687 ms   4e7b0801          MOVEC.L A0,VBR
 12, 1004CE:   7.517500 ms   303900FFFa00      MOVE.W ($FFFA00).L,D0
 15, 1004D4:   7.518187 ms   00400300          ORI.W #$300,D0
 17, 1004D8:   7.518562 ms   33c000FFFa00      MOVE.W D0,($FFFA00).L
 20, 1004DE:   7.519250 ms   08f9000e00FFFa04  BSET #$e,($FFFA04).L
 26, 1004E6:   7.520250 ms   103900FFFa17      MOVE.B ($FFFA17).L,D0
 30, 1004EC:   7.520937 ms   000000F0          ORI.B #$F0,D0
 32, 1004F0:   7.521312 ms   13c000FFFa17      MOVE.B D0,($FFFA17).L
 36, 1004F6:   7.522000 ms   08b9000700FFFa21  BCLR #$7,($FFFA21).L
```

```
Buffer char [80] size 80 bea "\0\0\0\0
Auto_Kathy_p struct .KATHY *C3E
Auto_Kathy_p ->Int1 long 1 (0x1)
y long -1431655750 (0xaaaaaaba)
x long -1464161553 (0xa8baaaef)
```

```
value_to_s(struct .KATHY *C3E )
toggle_case(char *C3E )
main()
```

```
Select a register to edit, then hit <Enter> or doubleclick or type new value directly.
```

Pull down Menus

Microsoft Windows 3.X based user interface

Speed bar (point and click)

On-line help

isassembler,
in-line
assembler
Window

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shows data
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me. This data
can be trans-
rted to other
Windows
programs
hrough DDE.

Register
Window

Source
Window

Data
Window

Watch Window
for High Level
variables

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Trace Buffer Window

C Call Stack

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CIRCLE 181 FOR U.S. RESPONSE CIRCLE 182 FOR RESPONSE OUTSIDE THE U.S.

FUTURE MEMORIES TO GET MORE BANDWIDTH

MEMORY SYSTEMS WILL REQUIRE FEWER DRAMS, BUT FASTER TRANSFERS OF DATA

Mike Farmwald
Founder, chief scientist, and vice president, Rambus Inc.

As DRAM densities continue to increase, computer systems need fewer and fewer DRAMs. At the same time, the bandwidth required from these few DRAMs continues to soar. To meet this demand, DRAM manufacturers are proposing a variety of faster DRAMs. The availability of these new types of DRAMs will lead to significant changes in the architecture of computers, from workstations to desktops to PDAs.

Today's memory requirements can now be satisfied in fewer packages than previously needed. By 1996, we expect that more than 50% of the DRAMs sold will be used in systems with four or fewer DRAMs. Two years later, we anticipate that over 50% of the DRAMs sold worldwide will be used in systems with exactly one DRAM. This trend implies that for all classes of computer systems and computational devices, the number of DRAMs per system is decreasing at approximately 25% per year (55%-30%). In addition, the sales trend is to significantly raise volumes at each successively lower-cost class of computational devices, resulting in an even faster transition toward fewer DRAMs per system.

At the same time that fewer DRAMs are being used per system, CPU data transfer rates and processing power are outstripping the capacity of memory systems to supply data. The result is a need for dramatically more bandwidth from memory subsystems consisting of a small number of DRAMs. Component manufacturers are responding by developing new devices that add capability to, and increase the speed of, an existing page mode DRAM core. There are several categories of such devices.

One class of device increases the width of the data bus on a conventional page mode DRAM. In addition, systems that need lots of bandwidth from fewer physical devices may not be well served by these devices because the DRAM cycle time doesn't change significantly from one generation to the next. The disadvantage of wider DRAMs and buses is the higher pin count on the controller, which drives up costs. An alternative approach enhances a standard page mode DRAM core to produce a specialized device. The video RAM (VRAM) is one such device that's been around for some time. Other types of specialized devices include the CDRAM, the EDRAM, and the SDRAM. The CDRAM adds an SRAM cache to a conventional DRAM core, producing a cached DRAM, or CDRAM. The CDRAM has separate address buses for the DRAM array and the SRAM, adding design flexibility. Tag RAM must be provided in the memory controller.

The enhanced DRAM or EDRAM, developed by Ramtron International, boosts performance by latching write cycles, thus retiring them quickly. The EDRAM also overlaps precharge time with data transfers and tweaks the speed of the DRAM array, achieving transfer cycle times of 15 (to the open page) or 35 ns. The synchronous DRAM or SDRAM adds a clock to the standard DRAM interface. It also latches both address and data lines, creating a pipeline for data transfers. These devices can move data in the open page at the full clock rate, which is either 66 (first generation devices) or 100 (second generation parts) MHz.

Rambus Inc. took a somewhat different approach with its RDRAM, which can transfer data at 500 Mbytes/s, using a fairly simple, 9-bit bus running at 2 ns per transfer. This interface was also developed into a standard for direct use by graphics controllers, processors, memory controllers, or other devices. Unlike the other DRAM technologies described, Rambus provides a complete design solution for the low-pin-count interconnect on standard pc boards.

Increasing the speed of DRAMs opens up opportunities for altering and, in many cases, simplifying, architectures in various ways. These new architectures can be used to lower component costs, improve performance, reduce power consumption, and simplify programming tasks.

One type of architectural innovation involves integrating the frame-buffer memory with system main memory. This type of unified architecture is already widely used in workstations, although it has yet to be employed in personal computers for two reasons. First, bus and main memory bandwidth in PCs isn't sufficient to provide good graphics system performance with a unified memory architecture. Second, the graphics subsystem in a PC has been commonly treated as an add-on or option by the system manufacturer because not all users want the same graphics subsystem when the technology transforms so rapidly. This will change as higher-performance CPUs (Pentium and RISC chips), high-speed buses (VL bus, PCI, etc.), faster DRAMs, and high-performance GUI chips proliferate.

Other architectural changes will include the integration of 2D and 3D graphics, full-motion video, audio and video encoding (NTSC), and decoding (MPEG, Indeo, etc.) into a single chip. These innovations will make high-quality multimedia and audio and video teleconferencing possible in a standard PC while using only moderate amounts of graphics memory (2 to 4 Mbytes).

This same, highly integrated technology is what will enable the next generation of game machines and set-top-boxes, where main memory, graphics (2-D and 3-D), audio, and full-motion video codecs are combined into one low-cost memory system (with no more than 4 Mbytes total for the entire system). These consumer systems are likely to be the volume drivers for DRAMs in the last half of the 1990s. ED

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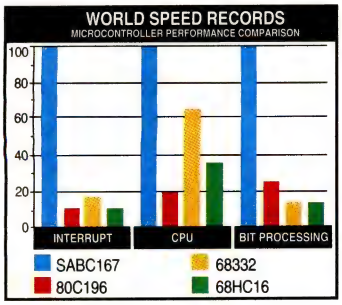

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A WORLDWIDE VISION OF MULTIMEDIA

INTERNATIONAL STANDARDS ARE EMERGING TO ASSURE MULTIMEDIA'S MARKET SUCCESS

Kevin McGarity
Senior vice president, Texas Instruments, Components Sector

AS WE MOVE FROM the textual/data processing world to one of full-motion video with integrated sound, a global vision is shaping the development of multimedia. In the past, technological achievement was segmented by geographic regions. Europeans focused on communications, Japanese set records for consumer goods, and Americans introduced computers. Meanwhile, other Pacific Rim companies concentrated on the proliferation of the computer market through pricing and performance innovations. Now, as multimedia emerges as one of the next major growth areas for semiconductors, industry members worldwide are sharing a technological vision and developing international standards for its success. In fact, image processing (compression) is one of the few technologies with standards set prior to de facto realization.

Multimedia consists of two primary technologies: visual and audio. Visual consists of graphics, such as 2D, 3D, and virtual reality; image processing, which utilizes various algorithms to enhance images; and compression technologies, such as JPEG, MPEG, h.261, and Px64 as part of H.320 for video telephony. Audio consists of audio compression, echo cancellation, audio amplification, and signal clarity, plus telephony, with its narrowbands, broadbands, and wireless focus.

While math-intensive digital signal processing (DSP) formulates the basis for addressing all of these technologies, fixed-point/floating-point programmable digital signal processors can most quickly and cost effectively meet the diverse requirements of multimedia's three market segments—consumer, computer, and communications.

By the year 2000, interactive enhanced-definition TV, with decoder boxes for broadcast on demand, will be commonplace in our homes. Digitally compressed cable-television systems will offer 10 times the number of current channels. And on-line access to databases, video games, and libraries through personal computers via both this cable and our telephone connections will dramatically enhance the widespread availability of detailed information.

Desktop computing is heading into new territory with document publishing. Scanners with character-recognition capability will overcome the problem of document capture in our all-digital computing world. Documents, once scanned, will be filed for information management. Plus, networking will tackle these ever-tougher challenges of exchanging still and motion pictures and images between computers as LAN highways introduce multimedia into the workplace.

In the communications area, video conferencing across continents can greatly increase productivity and reduce frequent travel. High-quality group video conferencing will integrate video, audio, and transmission processing for better resolution, faster motion, and larger displays.

Dedicated, evolving fixed-function digital signal processors will make new products more affordable and bring them into the mainstream sooner. Many of these products will evolve from programmable DSP devices now being used to solve many of today's multimedia applications.

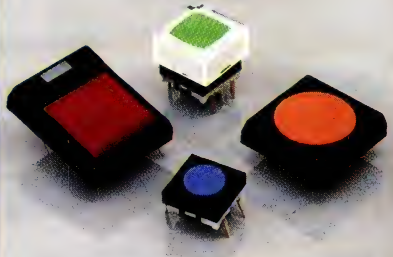
Today, the desktop computer as a multimedia device is in its infancy. Many aspects of the multimedia integration story are expected to parallel that of the computer graphics industry. In the late 1970s and early 1980s, computer graphics were available on dedicated graphic systems. They were expensive, and because of their cost, were utilized primarily for large industrial and business markets. Then, many companies brought graphics down to the board level with graphic-acceleration boards for mainframes and early personal computers. After that, those boards were integrated into chip sets. Finally, as VGA and other graphics became cost-effective single chips, they became an integral part of our PCs and workstations.

With video, large dedicated systems were initially very expensive. Integrating the systems onto several boards and adding them to a desktop computer reduced the cost of the function. Now as integration progresses, we're seeing single multimedia boards that perform multiple functions. Eventually, as video/audio systems are reduced to a single processing device, demand will increase and pricing barriers will come down.

Because multimedia is in its infancy, it's difficult to say how customer demand will affect the technology. It's safe to presume that multimedia will be embellished, and that technologies will become blurred, particularly in the areas of TVs and PCs. While MPEG, JPEG, and H.320 standards are defined, standards for the next generations of multimedia products are already underway. Silicon solutions must remain flexible, allowing processing technologies to adapt to them. For example, among TI's current multimedia offerings are PC image-board accelerators; audio MPEG decompression chips; video decompression chips for camcorders and TMS320C30, 'C31, and 'C50 digital signal processors used in PCs and video conferencing. Under development is a multimedia video processor (MVP), with DSP technology integrating audio and video on one chip.

The next few years will determine the key players in the national information super highway. As the cabling, telephony, and semiconductor players line up for their place in that highway, we plan to be there with our ATM devices, DSPs, MVP, and other developing products. We look forward to seeing you there, too, in the next century. ED

KEYS TO SUCCESS



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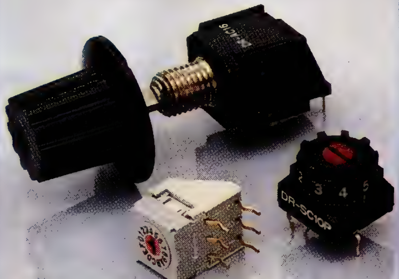

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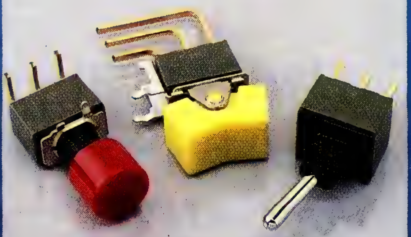
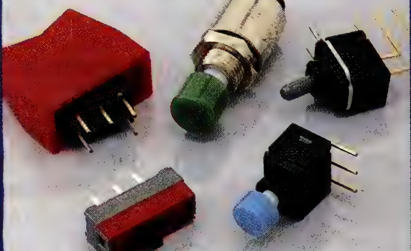


NKK washables lead the way with the industry's widest range of circuits, actuators, terminals & accessories. Micro thru std. sizes.

LITTLE GIANTS



NKK pioneered the smallest. Toggles, rocker, pushbutton, slides. Washables, SMDs, anti-static & STC contacts available.

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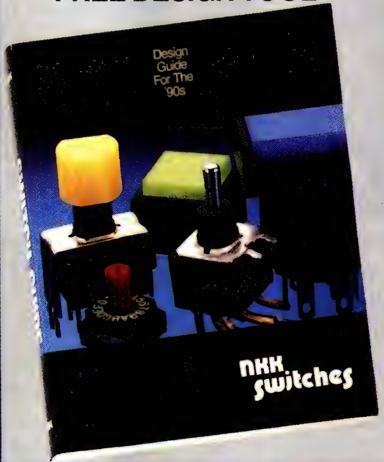

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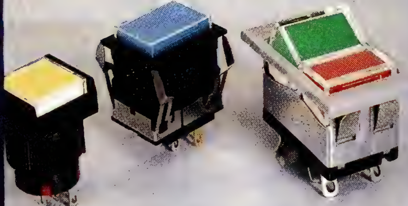

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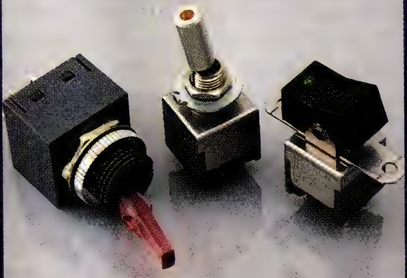
POINTS OF LIGHT



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A GUIDE TO REAL-TIME OPERATING SYSTEMS

Last year, at least 400 million microprocessors and microcontrollers were produced, finding their way into every device imaginable. About 90% of those microprocessors/controllers are "embedded" in products other than personal computers and workstations. At least half of them represent 4- and 8-bit ICs, adding processing smarts at low cost to automobiles, laser printers, TV set-top devices, and toys. What's more, a robust market is shaping up for the more powerful processors—by 1995, RISC and 32-bit processors, including digital signal processors, are expected to account for nearly one-third of the embedded processor market.

Plummeting costs for processors are pushing demand for sophisticated development tools and applications that exploit their processing power. Applications extend beyond process control, instrumentation, and defense to include communications by satellite, parallel processing, and multimedia. And where 4- and 8-bit processors can be commanded by a hundred to a thousand lines of code written in assembly language, RISC and 32-bit processors play host to applications consisting of up to a million lines of code written in a high-level language like C.

With a broad range of capable processors to choose from and a foundation of powerful workstations and PCs to develop on, developers writing applications face critical choices—both in the form of operating systems and development tools. Despite the existence of robust development environments, up to three quarters of developers still write their own operating-system kernels, core programs that supply executive services for managing tasks, memory, resources, as well as handling communication between tasks, task synchronization, and timer support. Makers of development systems are pulling out all the stops to bring "roll their own" developers into the fold. Reminiscent of the PC software arena in the Eighties, such hot competition is a boon for developers seeking powerful tools for embedded designs, because the array of capable, easy-to-use tools is growing. Tools that once ran only under Unix are now being ported to the PC and Windows 3.1. A drawback for users is the difficulty of sifting through vendors' claims: In the embedded world, traditional performance benchmarks and lists of features are less important than the suitability of tools for a particular application and how far the tools can stretch in helping developers solve the design problems bedeviling a project.

Some operating systems are optimized for particular applications. Microware, of Des Moines, Iowa, for instance, developed a drop-in extension to its OS-9. It enables the real-time playback of MPEG encoded audio and video files that can be input from optical, magnetic, or RAM disks, or from local or wide-area networks. In another example, the networking capabilities added to Integrated Systems' (Santa Clara, Calif.) pSOS kernel mean that the OS suits communication-intensive tasks like transaction processing.

To help developers, some companies offer evaluation versions of their tools. Though limited in functions, these tools nonetheless give developers an opportunity to test the fit between the application to be developed and the tools. What follows is an overview of most of the real-time operating systems (RTOS), their target processors, and their host development platforms. Pricing information, when it's available, is supplied in more general terms because some companies charge royalties for run-time licensing while others do not. Tool costs vary by target processors, and site licensing policies differ.

BY SHERRIE VAN TYLE

COMPUTING REAL-TIME OS GUIDE

▶ AMX

KADAK PRODUCTS LTD.

206-1847 West Broadway Ave., Vancouver, B.C., Canada V6J1Y5; (604) 734-2796; fax: (604) 734-8114

Overview and features: Real-time multitasking kernel with preemptive task scheduler, task prioritization, timing support, time slicing; task need not issue a request to AMX to receive a message

- C, C++, assembler supported
- InSight Debug tool breaks open ANX applications and gives the state of the system on a display
- ROMable

Target processors: Intel 80x86/8088, 80386, i960; Motorola 680x0, 68332, Z80, HD64180, 8085; MIPS R3000

Host platform: IBM PCs and compatibles

Price: AMX 3000 with full source code has a one-time license fee of $15,000 U.S. License fees for other targets range from $1900 to $4800 U.S. Contact the company for more details.

CIRCLE 585

▶ BYTE-BOS

BYTE-BOS INTEGRATED SYSTEMS

P. O. Box 3067, Del Mar, CA 92014; (800) 788-7288; (619) 755-8836

Overview and features: Multitasking operating system for use in real-time applications on a PC and wide range of embedded processors

- Preemptive task scheduling; time slicing; multithreading; dynamic and static task management; global resource management; fixed block memory management; ROMable
- Add-on components include "on-chip" stream serial I/O management; external UART stream serial I/O management; BOSVIEW multitasking monitor; profiler for task and code-section timing

Target processors: Intel 80x86, 8051, 8096, 80188; NEC V40/50, 25, 35; Motorola 68HC11, 68HC16, 680x0, 68332, 68340, 68302; Hitachi 6301/3, 6801/3 H8/500, H8/300; Zilog Z80, Z180, 64180; Mitsubishi 37700; Texas Instruments TMS320 C2x, C5x, C3x

Host platform: IBM PCs and compatibles

Price: Contact the company for pricing information.

CIRCLE 586

MICROKERNEL ARCHITECTURES IN REAL-TIME, EMBEDDED OSs

Atomic OS-9	Microware, Des Moines, Iowa
Chorus	Chorus Systems Inc., Beaverton, Ore.
CMX-Tiny **CMX-Tiny+**	CMX Co., Framingham, Mass.
Nanokernel	Ready Systems, Sunnyvale, Calif.
Nucleus Plus	Accelerated Technology, Mobile, Ala.
QNX Microkernel	QNX/Quantum, Kanata, Ontario, Canada
Tiny Tics	Tics Realtime, San Jose, Calif.
Wind	Wind River Systems, Alameda, Calif.

▶ C EXECUTIVE

JMI SOFTWARE SYSTEMS INC.

904 Sheble Lane, P.O. Box 481, Spring House, PA 19477; (215) 628-0840; fax: (215) 628-0353

Overview and features: C Executive, written mostly in portable C code, supplies execution environment for C-language multitasking embedded systems; includes interrupt-driven device drivers, real-time clock support, fully preemptive prioritized task schedule, automatic opening and closing of standard files, portable C library; CE-DOSFILE maintains media-compatibility with DOS

- ROMable
- Built-in data-flow design facilities, built-in I/O subsystem, device drivers written in C; about 5% written in assembly code for task scheduling, context switching, interrupt handling, and block data moves.
- CE-TCP supports TCP, IP, UDP, ART, ICMP, SLIP

Target processors: MIPS R3000; AMD 29K; Transputer; Intel 8086/8088/80x86, 80186/80188, i860, i960, 8080/8085; Zilog Z80; Motorola MC68xxx, MC6809; TI TMS34010/20; National 32000; Intergraph Clipper; DEC LSI-11

Host platform: IBM PCs and compatibles

Price: Initial development copy of C Executive is $2500, $3750 with CE-DOSFILE; additional copies are $350 for quantities of 2 to 9, $500 with CE-DOSFILE; source licensing and licensing for multiple versions are available. Contact the company for further information.

CIRCLE 587

▶ CMX

CMX CO.

19 Indian Head Heights, Framingham, MA 01701; (508) 872-7675

Overview and features: Preemptive, multitasking OS, supports nested interrupts, interfaces to assembly language

- ROMable
- TINY, TINY+ OS microkernels; Tiny + needs no external RAM; on-board ROM supports user application code and OS code; supplies preemptive scheduling, cooperative scheduling available; no royalties

Target processors: Intel 8051, 80961/80196, 68HC11; Mitsubishi 37100 family; Siemens 80C166/67; Hitachi H813xx, H815xx; SGS-Thomson ST-9; NEC 78K2, 78K3

Host platform: IBM PCs and compatibles

Price: Single-user license is $795, site license goes for $1425, development tools are $475.

CIRCLE 588

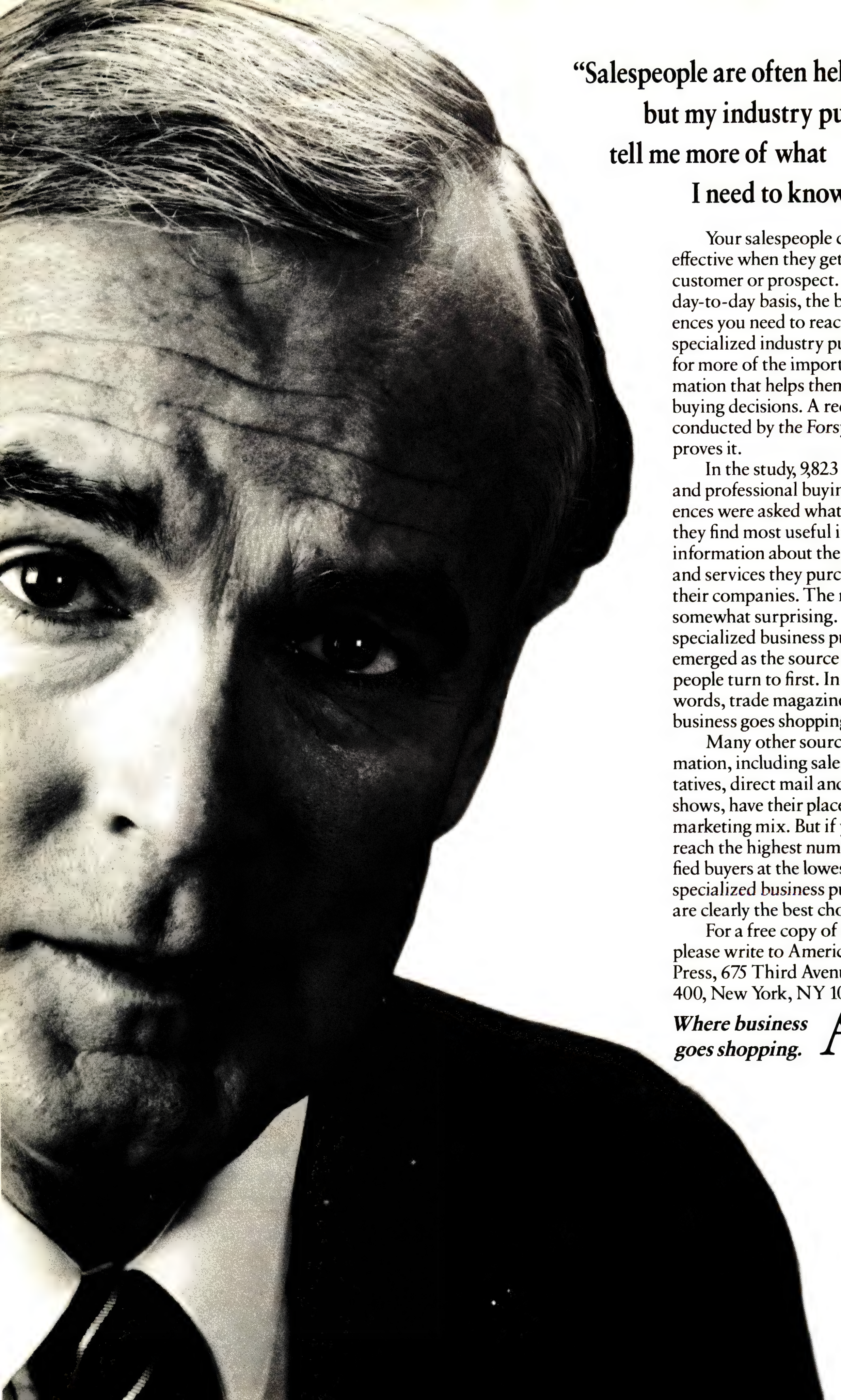
▶ EMBEDDED DOS

GENERAL SOFTWARE

P. O. Box 2571, Redmond, WA 98073; (206) 391-4285; fax: (206) 557-0736

Overview and features: Fully-reentrant, DOS-compatible operating system; implements standard DOS programming interfaces, enabling developers to write embedded code in C, C++, Turbo Assembler, Ada, or other languages, as well as use third-party libraries.

- Multitasking microkernel has 48 services callable from C or



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In the study, 9,823 business and professional buying influences were asked what sources they find most useful in providing information about the products and services they purchase for their companies. The results were somewhat surprising. Overall, specialized business publications emerged as the source business people turn to first. In other words, trade magazines are where business goes shopping.

Many other sources of information, including sales representatives, direct mail and trade shows, have their place in the total marketing mix. But if you want to reach the highest number of qualified buyers at the lowest cost, specialized business publications are clearly the best choice.

For a free copy of the study, please write to American Business Press, 675 Third Avenue, Suite 400, New York, NY 10017.

Where business goes shopping. **ABP**

assembly, dynamic thread allocation, asynchronous communication between cooperating threads, multithreaded (reentrant) operation; integrated kernel debugger, and configuration options
- CodeProbe Software Analyzer captures OS events, time-stamping them for analysis; supports third-party real-time kernels and executives when these kernels use software-interrupt APIs

Target processors: Intel 8086, i86, 286, 386, 486, V25, V35; Chips and Technologies 8680
Host platform: IBM PCs and compatibles
Price: Codeprobe real-time software analyzer goes for $350; an Embedded DOS Commercial Kit with source and distribution license is $995; an evaluation kit costs $495. Other prices are available from the company.

CIRCLE 589

▶ LynxOS
LYNX REAL-TIME SYSTEMS INC.
16780 Lark Ave., Los Gatos, CA 95030; (408) 354-7770; fax: (408) 354-7085

Overview and features: Unix-compatible, POSIX-conforming, multitasking OS has 256 user-defined priority levels and preemptible kernel; is reentrant and compact
- Conforms to POSIX 1003.1 standard, with real-time extensions (1003.4 Draft 9) and threads extensions (1003.4a)
- Development tools include utilities, compilers, assemblers, debuggers, linkers, libraries, and header files; device drivers can be loaded and unloaded while the system is running
- Binary- and source-code compatible with AT&T Unix V3.2 and source-code compatible with Unix BSD 4.3; supports TCP/IP, NFS, X Windows, and OSF Motif
- TCP/IP based on BSD Networking Distribution (socket based); support for developing Streams drivers, modules, and applications; includes a Streams mapping driver to support applications using TCP/IP protocol based on TLI library functions; NetBoot PROM for remote booting from a server
- Ada implementation based on PSDIX.4 threads
- ROMable kernel

Target processors: Intel 386, 486 i860; Motorola 68030, 68040, 88000; Sun Sparc 2; MIPS R3000; IBM RS/6000, PowerPC; AMD 29000
Host platform: IBM PCs and compatibles, Unix workstations
Price: Contact the company for pricing information.

CIRCLE 590

▶ MTOS-UX
INDUSTRIAL PROGRAMMING INC.
100 Jericho Quadrangle, Jericho, NY 11753; (516) 938-6600; fax: (516) 938-6609

Overview and features: MTOS-UX for 68000, 88000, 80x86, 80860 supports symmetrical, multiprocessor configurations (up to 16 CPUs); enables creation of dynamic objects; includes Unix portable library; DOS-compatible file system available; ANSI C compatible; supports TCP/IP, UDP, IP, SLIP protocols
- MTOS-UX/88K multiprocessing, multitasking OS for 88000 RISC is optimized for concurrent execution on up to 16 CPUs; has test facilities, debugging tools, validation programs, and configuration files; drivers may be written in C; optional DOS-compatible file system
- MTOS-UX/386/486 is compatible with DOS, Unix development hosts; has an unlimited number of system objects; available DOS-compatible file system
- MTOS-68K OS accommodates 2048 tasks and handles up to 16 (68000) processors on common bus; requires only a clock interrupt and a lockable bus to runs in any 68000 environment
- MTOS-86 runs on any 8086 configuration, supports 8087; 5 to 9 kbytes of storage needed for configurable nucleus

Target processors: Motorola 88000, 680x0; Intel 8086, 8088
Host platforms: IBM PCs and compatibles, Unix workstations
Price: MTOS-UX/68K, 86, 386, 88K development kits start at $5000; MTOS-UX/Ada starts at $45,000. Contact the company for other pricing information.

CIRCLE 591

▶ MULTITASK
US SOFTWARE
14215 NW Science Park Dr., Portland, OR 97229; (503) 641-8446 or (800) 356-7097; fax: (503) 644-2413

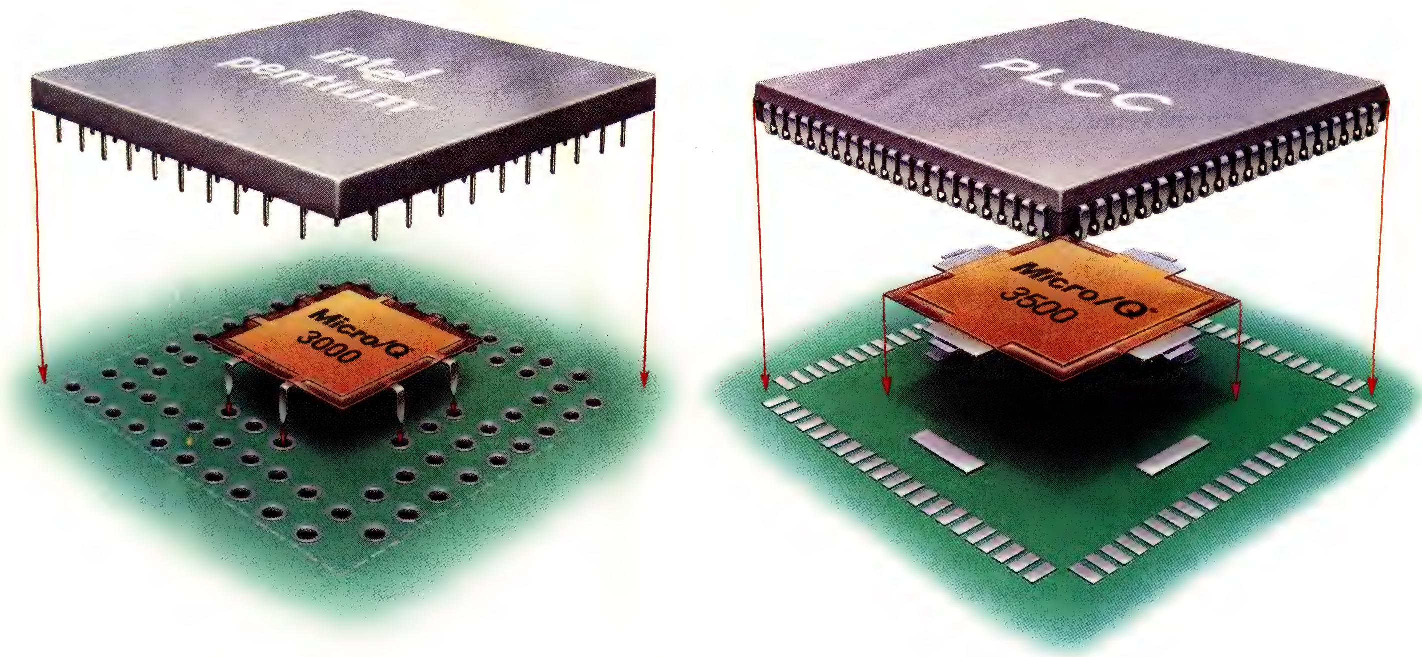
Overview and features: MultiTask! executives develop and implement real-time multitasking applications using 60 system calls; ANSI C source code
- The ViewTask! PC development tool for multitasking designs, develops, and tests real-time multitasking applications; ViewTask! libraries can be used to compile and begin testing in a PC environment
- ProtoTask! prototyping tool for multitasking is PC- or target-operable to develop, prototype, and test applications; task-level debugger works alone or with host-based debugger
- USNET supports Ethernet or serial TCP/IP applications and protocols, including FTP, TFTP, BOOTP, SLIP, TCP, UDP, IP, ICMP, ARP, RARP
- GOFAST! floating-point libraries and emulators are for C compilers

Target processors: Motorola 680x0, 683xx, 68HC11; Intel 386 protected mode, 8051, 80196, Z180, 68HC16, i960, R3000, Sparc
Host platforms: IBM PCs and compatibles, Unix workstations, DEC VAX
Price: Contact the company for pricing information.

CIRCLE 592

▶ NUCLEUS RTX
ACCELERATED TECHNOLOGY INC.
P.O. Box 850245, Mobile, AL 36685; (800) 468-6853; (205) 661-5770; fax: (205) 661-5788

Overview and features Real-time, multitasking executive; priority-based, preemptive/nonpreemptive, time-slicing kernel; C source code supplied
- Nucleus PLUS: 95% C code, 5% processor-specific assembly language; executes 30% to 50% faster than Nucleus RTX; extends RTX to include dynamic creation of PLUS objects,



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queues, mailboxes, timers, pipes, and an Advanced Interrupt Management Mechanism to eliminate interrupt latencies
- Nucleus NET networking protocols for interoperability between RTX- or PLUS-based systems and other TCP/IP- or UDP/IP-based systems
- Nucleus File supplies file I/O support for Nucleus RTX and PLUS applications; reentrant; DOS-compatible. File is for floppy and hard disks; C source code supplied

Target processors: AMD Am29xxx; Analog Devices 2100/21000; Fujitsu SPARC Lite; NEC 783xx; Intel 80x86 real mode, 80386/486 protected mode, 8096/196; Motorola 680x0, 683xx, 68HC11/16, 96000, 56xxx DSP; Texas Instruments TMS320Cxx; VLSI/GES Plessey ARM 60; Siemens 80C166

Host platform: IBM PCs and compatibles

Price: Nucleus RTX system 80x86 real-mode and Motorola 68xxx are $3,495; 80x86 protected mode with DOS extender is $4995.

CIRCLE 593

▶ OS-9

MICROWARE SYSTEMS CORP.

1900 NW 114th St., Des Moines, IA 50325-7077; (515) 224-1929; fax: (515) 224-1352

Overview and features: OS-9 modular OS supplies deterministic operation for 680x0 applications with preemptive task switching, process execution control, flexible interrupt-service routines; extensions support graphics, networking, and multimedia
- FasTrack environment simplifies and automates tasks in creating, debugging, analyzing, and managing software projects; integrates version control for development teams; automatic generation of makefiles; one-button "build, download, and execute"; includes Ultra C ANSI C compiler
- Atomic OS-9 microkernel stands alone with I/O drivers or supports a unified I/O manager using existing file manager
- Motion Picture File Manager extends OS-9 for real-time playback of MPEG encoded audio and video files input from optical, magnetic, or RAM disks; includes RAVE multimedia development tool and user interface

DIGITAL SIGNAL PROCESSING GOES REAL-TIME

Facsimile and speech synthesis typify just two of the applications for programmable, general-purpose digital signal processors. More and more, these powerful DSP ICs are taking the place of dedicated plug-in cards for fax machines and telephone answering. Developed by such vendors as Analog Devices, Motorola, and Texas Instruments, these processors handle the high-speed I/O and fast, real-time mathematical computations that are required by multimedia applications. They can run multiple programs at once thanks to real-time operating systems that combine a preemptive, multitasking OS kernel with mathematical and signal-processing algorithms targeting applications in multimedia and telecommunications. Following are two such operating systems aimed at DSP ICs and applications:

▶ SPOX

SPECTRON MICROSYSTEMS INC.

320 Storke Rd., Goleta, CA 93117; (805) 968-5100; fax: (805) 968-9770

Overview and features: SPOX-KNL real-time multitasking kernel for single and multiprocessor applications; modular; multiprocessing applications can be developed and debugged on a single-CPU system and migrated to a multiprocessor system without changes to application source code
- SPOX-DBUG extends TI's C source debuggers, enabling developers to inspect and modify semaphores, queues, mailboxes, and other system structures; delivers performance monitoring and tuning functions
- SPOX-LINK connects embedded SPOX applications to host environments—DOS, OS/9, VxWorks, and Windows
- SPOX libraries for floating-point processors contain signal processing functions, such as convolution, correlation, windowing, fast Fourier transforms, two-dimensional FFTs, and filer functions (including FIR, IIR, and LMS adaptive filtering); supports dynamic allocation of arrays from on-chip RAM, external SRAM, and bulk DRAM; extensible so that multimedia developers can modify or augment functions with their own algorithms for image processing, speech recognition, video compression, and decompression

Target processors: Texas Instruments TMS320C3x/4x/5x; Analog Devices ADSP210xx, 21xx; Motorola 9600x, 5600x

Host platforms: IBM PC, Sun workstations

Price: Contact the company for pricing information.

CIRCLE 594

▶ TARTAN

TARTAN

300 Oxford Dr., Monroeville, PA 15146; (412) 856-3600; fax: (412) 856-3636

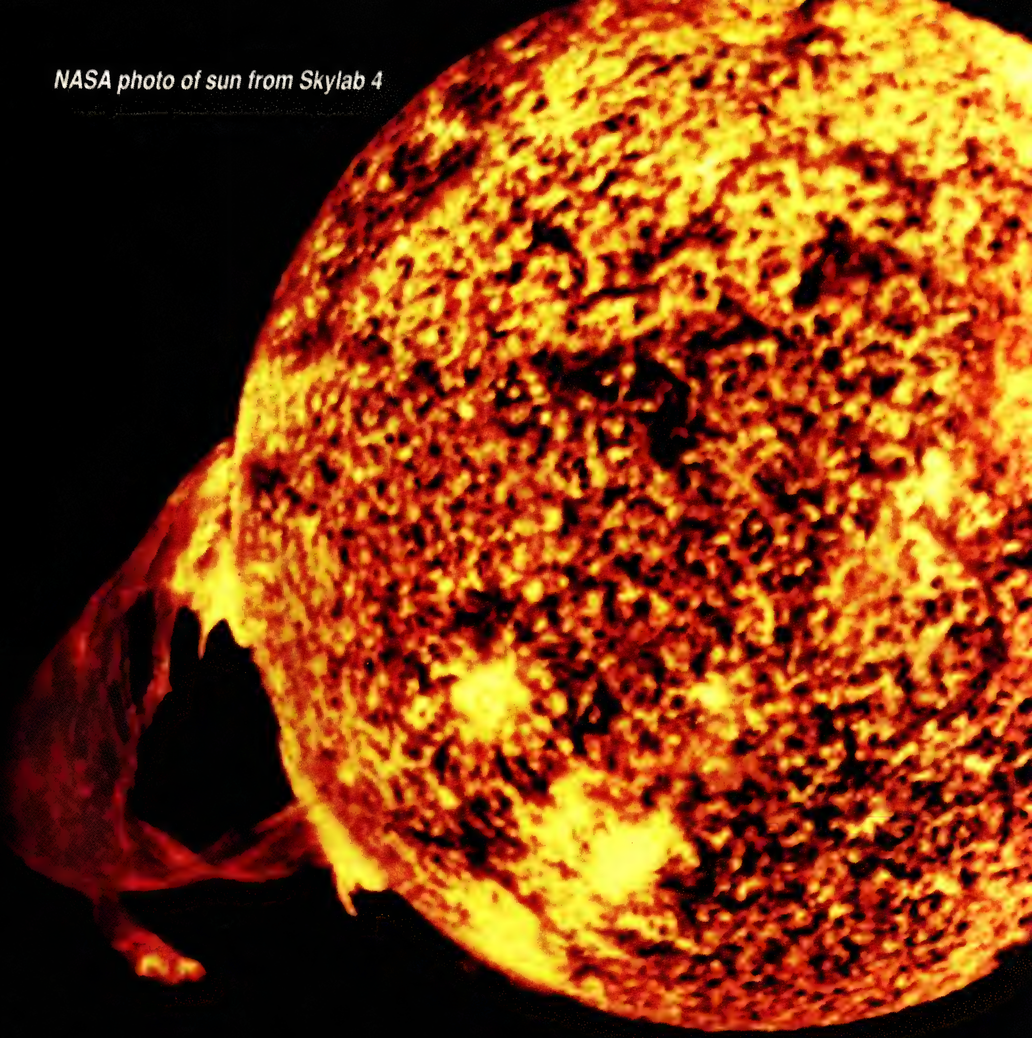
Overview and features: Ada development systems for digital signal processors, including compilers, debuggers, simulators, emulator support, linkers, assemblers, librarians, run-time executives, and run-time libraries; FasTar, VecTar, and SigTar DSP math libraries; FloTar double precision floating-point math library; Tartan C++ compilers for Texas Instruments' TMS320C3x and TMS320C4x digital signal processors; TartanWorks—integrates Wind River Systems' VxWorks RTOS with Tartan's Ada Development system for Motorola 68xxx

Target processors: Intel i960 MC and MX avionics, Motorola 68xxx, TI C3x and C40 DSP ICs and MIL-STD-1750A.

Host platforms: Sun Sparcstations under SunOS or Solaris, DEC VAX under VMS; DOS, OS/2 PCs

Price: VecTar and SigTar are $695 on PCs; $895 on Sun Sparc. Other prices are available from the company.

CIRCLE 595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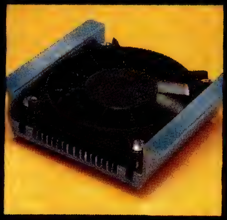

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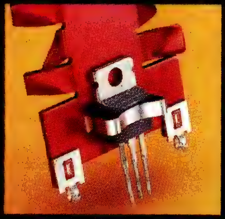

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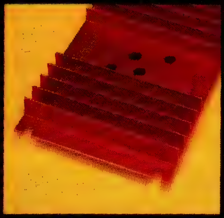

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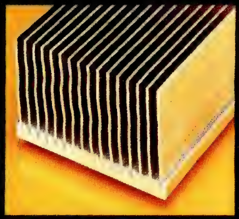

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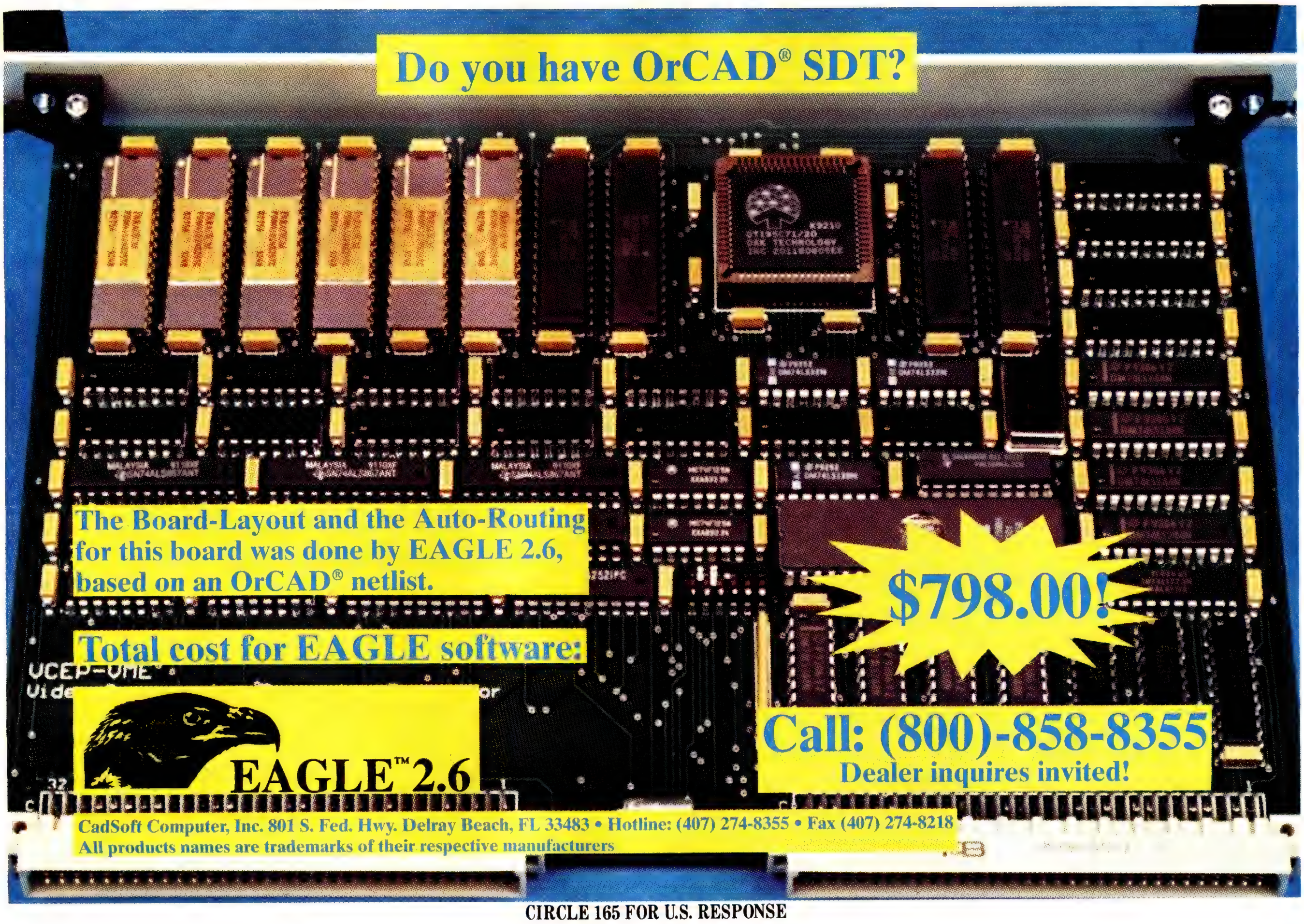

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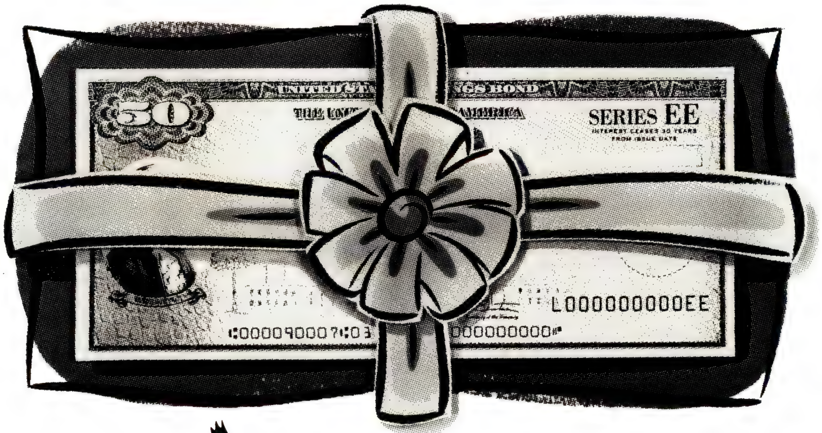

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- Implements MIT's X Windows System
- ISDN File Manager supplies ISDN support for use in wide-area networking and telecommunication products
- Multiprocessor support
- ROMable
- Extended OS-9 adds support for NFS and TCP/IP networking over Ethernet or serial line (SLIP)

Target processors: Motorola 680x0, Intel 80386/486
Host platforms: Sun 3, Sun 4 workstations, Sparcstation, HP9000
Price: Developer's package for OS-9 version 3 starts at $4000 for Motorola processors. FasTrak, including the Ultra C compiler, goes for $14,500 for up to five networked workstations. Contact the company for other pricing information.

CIRCLE 596

▶ OS/OPEN
IBM CORP.

P.O. Box 100, Somers, NY 10589; (914) 766-1900

Overview and features: Scalable, real-time OS and development tools for PowerPC 601 RISC processor; modular architecture; POSIX real-time executive; DOS file system, remote debugger; ANSI C library; open-shell native-system debugging and exercising; the smallest kernel is 32 kbytes
- RISCWatch 601 works as assembly-level debugger during hardware design and source-level debugger during application software development; tool available for debugging PowerPC 601 products before hardware is functioning
- TCP/IP networking protocol interfaces (ported from BSD 4.3); network interface support for Token Ring, SLIP, and Ethernet

Target processors: PowerPC 601 and later releases, PowerPC embedded controllers (slated for release in first half of 1994)
Host systems: IBM RS6000, Sun workstations
Price: Single-user development license is $19,500; royalty licensing agreements are based on volume. RISCWatch 601 goes for $22,500.

CIRCLE 597

▶ PDOS
EYRING CORP.

Systems Software Div., 1450 West 820 North, Provo, UT 84601; (801) 375-2434 or (800) 937-7367; fax: (801) 377-3850

Overview and features: PDOS 4.2 real-time OS for Motorola 680x0, 683xx processor families has preemptive, prioritized task scheduling; fast, deterministic response; multitasking executing; multiprocessor support; multiuser capability; embedded kernel modularity; and is written in Motorola 68000 assembly language
- PXROM porting kit supplies tools to embed in building block format, including PDOS kernel, flat file system, hierarchical file system, RAM disk, network facilities, monitor, and debugger; support range from single processor, single task to multitasking; multiprocessor system with networking and mass storage
- Implemented as native PDOS in bootable target system, in EPROM, and in embedded PDOS modules
- Full Spectrum development kits support C language development on PC, Sun, HP, and VAX hosts; board support package for Alsys Ada compiler extends Ethernet support to application development and execution
- PDOS/MS-DOS Backplane Communications Services enables PC host and 68000 target to communicate over VME backplane instead of RS-232 connection to speed file transfer and shorten debugging time
- PXNET communication support DARPA Internet protocols, supplies socket and link-level library support; also supports TCP/IP protocols

Target processors: Motorola 680x0, 683xx
Host platforms: IBM PCs, DEC VAX, Hewlett-Packard, Sun
Price: Contact the company for pricing information.

CIRCLE 598

▶ PRECISE/MQX
PRECISE SOFTWARE TECHNOLOGIES INC.

Suite 308, 301 Moodie Dr., Nepean, Ontario, Canada K2H 9C4; (613) 596-2251; fax: (613) 596-6713

Overview and features: Real-time executive for multiprocessing, multitasking, memory and buffer management, intertask communication, and interrupt management; modular; source-code supplied, 95% C, 5% assembly language
- Precise/RTCS TCP/IP real-time communication server is an embedded I/O component that supports ARPA networking protocols; RTCS supplies an API supporting the Berkeley Socket model and the Raw model, simplifying integration of RTCS firmware with embedded Unix or Unix workstation-based applications
- Precise/DLCS data-link communication server is an embedded I/O component supplying serial SDLC and asynchronous communication services; implemented in ANSI C
- Precise/MCS communication server is an embedded I/O component supporting MIL-BUS hardware operating as a bus controller or remote terminal; implemented in ANSI C
- Multiprocessor software debugging tools
- Support for TCP/IP, LAPB, SDLC, MIL-STD-1553, IEEE-488

Target processors: Motorola 680x0, 683xx, DSP96002; Intel 80x86, 80x88; Texas Instruments TMS320C30/40
Host platforms: IBM PCs and compatibles, Sun workstations
Price: Contact the company for pricing information.

CIRCLE 599

▶ pSOS
INTEGRATED SYSTEMS INC.

3260 Jay St., Santa Clara, CA 95054-3309; (408) 980-1500; fax: (408) 980-0400

Overview and features: pSOSystem integrates pSOS+ real-time kernel, Unix-standard networking, Ada, C, C++ compilers, libraries, and debuggers; W-Window System graphics; file-system support
- Multiprocessing version of the kernel (pSOS+m) enables application tasks to be distributed across processor nodes

- pSOSystem/386 has a C/C++ compiler and source-level debugger for an embedded 386 processor (i386 EX)
- pSOSystem/OpEN expedites designing and implementing embedded-systems-based networked peripherals; includes standard sockets and TLI/XTI interface between pSOSystem applications and Unix-compatible Streams facility
- Streams layer includes a connection to an embedded/real-time optimized TCP/IP protocol stack to access TCP/IP-based networks like Ethernet; OpEN accesses pSOSystem network device library, supplying connections to Ethernet, SLIP, PPP, and others
- pX11+ X Window system displays output and reading input from X server on Internet network; also can be used to build Motif and OpenLook interfaces

Target processors: Motorola 68xxx, 88xxx, Intel 8086, 386, i386 EX, and i960
Host platform: Unix workstations
Price: pSOSystem/36 EX prices begin at $7000. Other prices are available from the company.

CIRCLE 600

▶ QNX
QNX/QUANTUM SOFTWARE SYSTEMS LTD.

175 Terence Matthews Crescent, Kanata, Ontario K2M1W8;
(613) 591-0931

Overview and features: POSIX-compliant, real-time, scalable OS; by including or excluding various resources at run-time, QNX scales down to ROM-based system or up to encompass hundreds of processors either tightly or loosely connected by LAN technologies; maintained transparently throughout the distributed environment
- QNX microkernel requires 8 kbytes, consists of process scheduler, interrupt redirector, and interprocess communication handler; all system services are built on message-passing primitives; variations on the IPC primitives, such as message queues, are implemented as servers employing lower-level services; processes can request that messages be delivered in priority order, rather than in time order
- TCP/IP, X.25

Target processor: Intel 80x86
Host platforms IBM PC AT, PS/2, and compatibles
Price: Contact the company for pricing information.

CIRCLE 601

▶ RTMX
RTMX INC.

3333 Chapel Hill Blvd., Suite D200, Durham, NC 27707;
(919) 493-1451; fax: (919) 490-2903; e-mail: krl@rtmx-uniflex.com

Overview and features: RTMX/RT run-time POSIX 1003.1 and 1003.2 compliant with POSIX 1003.4 (draft) extensions; RTMX/RN networking development system, including utilities, compilers, libraries; is user-configurable; RTMX/RX networking and X Windows V11R5 and Motif 1.2.2 system
- Built on NET/2 release of Berkeley BSD, with the addition of 1003.1, 1003.2, 1003.4 Draft real-time extensions
- GNU ANSI C, C++ source-level debugger, System V-compatible C library
- Supports 68881, 68882, 80387, MC68040 floating-point units
- Berkeley BSD source-compatible socket library, support for TCP/IP and OSI
- Has X Windows System option, including MIT X11.5, X libraries, OSF/Motif's graphical user interface and Windows Manager

Target processors: Motorola MC68040, MC88100/110; Intel i860, 80386, 90486, Sparc 2
Host platform: IBM PCs and compatibles
Price: RTMX/RN development system has end-user license list price of $1995, while an OEM site license for RTMX/RX goes for $14,975 per CPU type. Object code fees range from $395 to $49,000 depending on quantity, target, and development systems. Contact the company for additional pricing information.

CIRCLE 602

▶ RTXC
A.T. BARRETT & ASSOCIATES

11501 Chimney Rock, Suite R, Houston, TX 77035-2900;
(713) 728-9688; fax: (713) 728-1049

Overview and features: RTXC package includes source code for RTXC real-time kernel, system generation utilities, debugger, and other utilities; 600-page user manual
- Written in C, RTXC is easily ported to new processors; ROMable
- Version 3.1 has dynamic task creation, time slicing, and improved handling timeouts and timers

Target processors: AMD 29k/292xx, 294xx; Hitachi 6303, H8/300, H8/500; Intel iAPX 80x86, 80x96, 80x51; Motorola MC680x0, M68HC11, 16; NEC V25/V53; Siemens 166/167; TI TMS 320C30; TI 340x0; Zilog Z80/Z180
Host platform: IBM PCs and compatibles
Price: Prices depend on primary and secondary licensing. Call the company for detailed information.

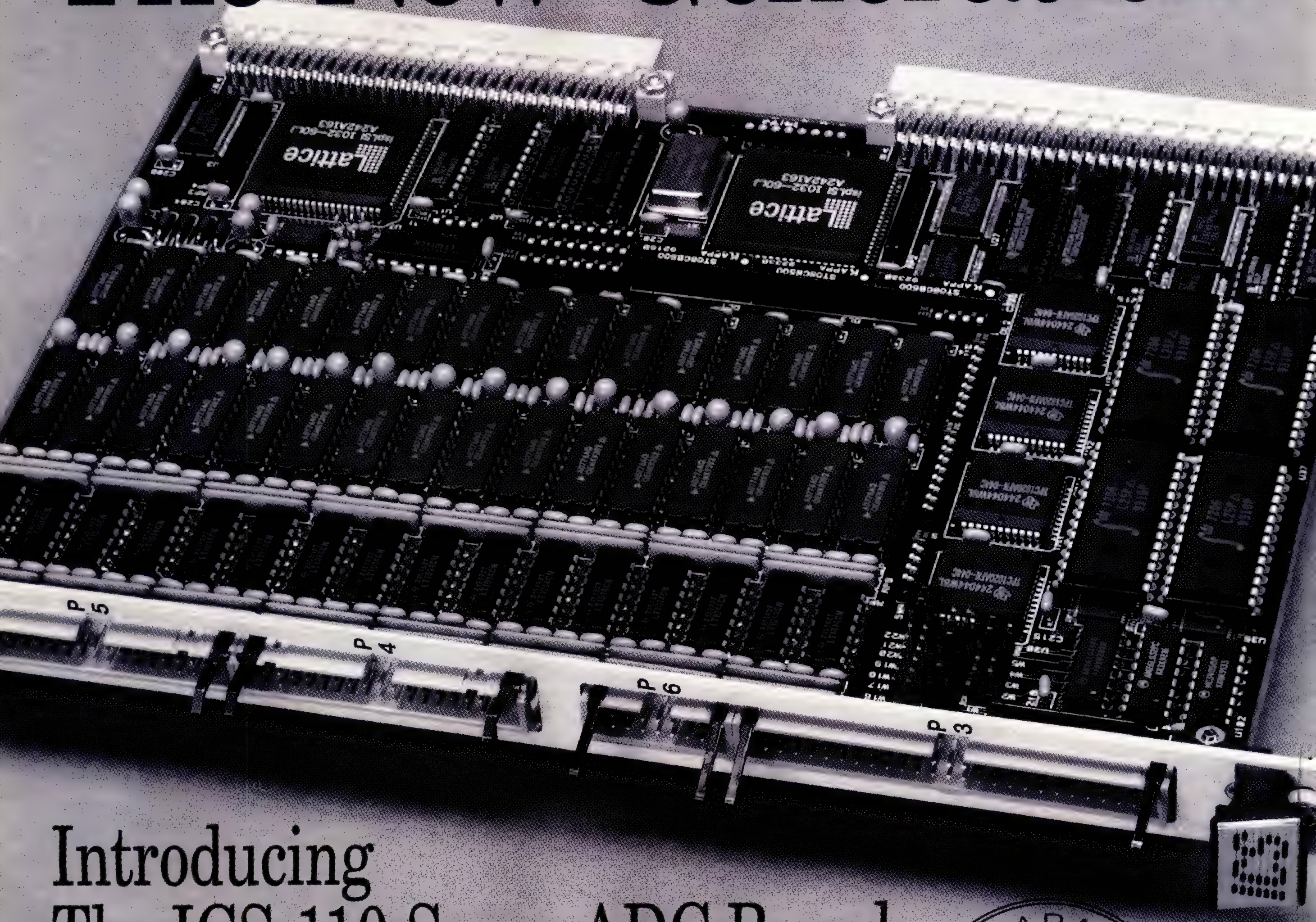
CIRCLE 603

▶ TICS
TICS REALTIME

1584 Camden Village Circle, San Jose, CA 95124; (408) 723-2200; fax: (408) 723-2200

Overview and features: • Tics kernel features preemptive, cooperative, and time-slicing modes that can be combined in one application; cooperative tasks may share a common stack; less than 8 kbytes, ROMable; includes multitasking serial communication library
- Object-oriented; task instances can be created with their own instance data; can be used with Turbo C++ for real-time OO programming
- Tiny Tics round-robin kernel requires less than 500 bytes of code for single-chip controls like the Intel 8051; runs on the chip without external RAM or EPROM
- Pause, one-shot, and periodic timers supplied
- C source code for kernel
- DOS-compatible; Tics reprograms PC timer chip to devel-

The New Generation



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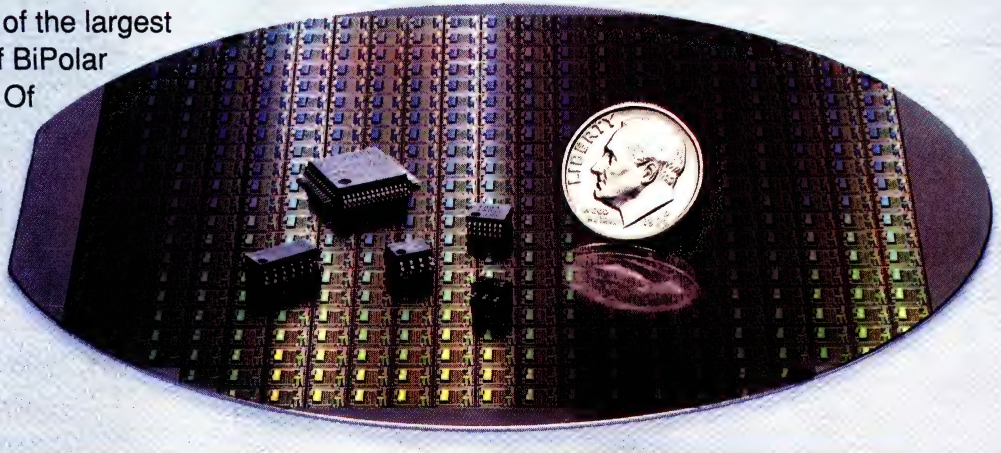

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NJU3712	8-bit Serial In Parallel Out with Cascade Function	D, M16
NJU3713	12-bit Serial In Parallel Out	D, G18
NJU3714	12-bit Serial In Parallel Out with Cascade Function	D, G20
NJU3715	16-bit Serial In Parallel Out	L, G22
NJU3716	16-bit Serial In Parallel Out with Cascade Function	L, DMP24
NJU3718	20-bit Serial In Parallel Out with Cascade Function	L, G28
NJU3719	24-bit Serial In Parallel Out	L15

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CIRCLE 183 FOR U.S. RESPONSE   CIRCLE 184 FOR RESPONSE OUTSIDE THE U.S.

oper-specified granularity
Target processors: With minor modifications, supports any target processor with an available C cross compiler
Host platform: IBM PCs and compatibles
Price: Single-user price is $499; single-site license is $998.

CIRCLE 604

▶ VENIX
VENTURECOM

215 First St., Cambridge, MA 02142; (617) 661-1230; fax: (617) 577-1607
Overview and features: VENIX 4.2.1 real-time OS is compatible with Unix System V Release 4.2 source code from Novell/Unix System Laboratories; includes kernel preemption, determinism, asynchronous I/O, contiguous file system, and memory locking
- Integral X-Windows, Motif, and OpenLook graphical user interfaces
- Bundled support for TCP/IP and NFS
- Conforms to IEEE POSIX 1003.1

Target processors: Intel 80386, 80486, Pentium
Host platform: Unix workstations
Price: Workstation system, including RTOS, is $995; development system with ANSI C compiler, function library, utilities, and device drivers goes for $2395

CIRCLE 605

▶ VRTX
READY SYSTEMS

470 Potrero Ave., Sunnyvale, CA 94086; (800) 321-2636 or (408) 736-2600; fax: (408) 522-7197
Overview and features: VRTX/OS 3.0 modular, deterministic, preemptive, priority-based task scheduling; intertask communication and synchronization facilities; dynamic memory allocation; optional time-sliced operations
- VRTXsa-scalable, upwardly compatible kernel based on Nanokernel architecture; supports range of APIs, presents different APIs to various parts of application within a single processor; permits reuse of code across applications; supports message broadcasting; support for variable-size heaps; KernelIntegrator, KernelBuilder toolkits for integrating existing in-house kernels and ease migration from proprietary to commercially supported environment
- VRTX32 kernel supports dynamic memory allocation for short-term data storage (fixed size pools); system calls for real-time clock, character I/O, interrupt handling, and initialization
- Spectra open cross-development backplane; run-time independent, can be used with a bare board or VRTXsa, VRTX32, or in-house kernels; supports remote debugging; eases reuse of code by means of upward compatibility; reusable device drivers; Microtec's XRAY Debugger available for Spectra (Microtec Research, Santa Clara, Calif., recently merged with Ready Systems)
- Virtual Target, a host-based emulation of the target system affords early prototyping without stable hardware
- SNX Streams networking executive implements TCP/IP protocols; Internet suite includes TCP, UDP, IP, ICMP, ART, RARP; NFS support for transparent access to distributed file systems

Target processors: Motorola 680x0, 683xx
Host platforms: Unix workstations, IBM PCs and compatibles under Windows 3.1 in the first quarter of 1994
Price: Call the company for pricing information.

CIRCLE 606

▶ VXWORKS, MICROWORKS
WIND RIVER SYSTEMS INC.

1010 Atlantic Ave., Alameda, CA 94501; (510) 748-4100; fax: (510) 814-2010
Overview and features: VxWorks 5.1, MicroWorks scalable real-time operating systems; VxWorks bundled with core tools for development, including an interactive shell, remote source-level debugger, C compiler, and an incremental loader; used for high-level applications; VxWorks includes standard networking, supports NFS as well as POSIX, ANSI C, and Unix networking
- Wind's microkernel supplies task management, synchronization, system clock, and timing facilities; MicroWorks' OS primitives add dynamic memory management, quick interrupt support, optimized floating-point support, and flexible intertask communications; modular, configurable
- VxMon, on the target board, acts as MicroWorks' run-time debugging agent
- MicroWorks toolset includes ANSI-C cross-compiler, assembler, Unix-compatible liner, and other tools; VxGDB debugger does remote debugging of MicroWorks application over dedicated serial link
- WindView graphical debugging and analysis tools; Wind C++ Gateway for ObjectCenter C++ development tools; StethoScope graphical monitoring and profiling tool; VxSim simulation tools running on Sun workstations

Target processors: Intel 80960, Motorola 68xxx, Sparc, SPARC Lite, MIPS R3000
Host platforms: Unix workstations (Sun, HP, DEC, IBM, Silicon Graphics); VXWorks for Windows will run on IBM PCs and compatibles in January, 1994
Price: VxWorks for Windows starts at $12,500 for 10-user license; WindView is $4995 for a single-user license; other prices are available from the company.

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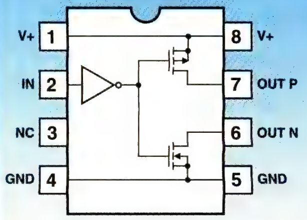
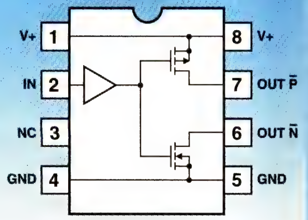


Non-Inverting

- Isolated Drains
- 20 ns Switching Time
- $1.96 – 100's P-DIP

EL7114

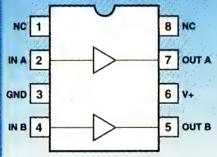


Inverting

- Isolated Drains
- 20 ns Switching Time
- $1.96 – 100's P-DIP

Dual Channel, 2.0 Amps Output

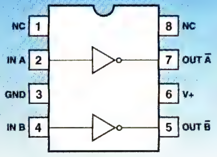
EL7202



Non-Inverting

- 20 ns Prop Delay
- 20 ns Switch. Time
- $1.96 – 100's P-DIP

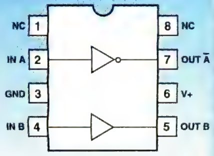
EL7212



Inverting

- 20 ns Prop Delay
- 20 ns Switch. Time
- $1.96 – 100's P-DIP

EL7222

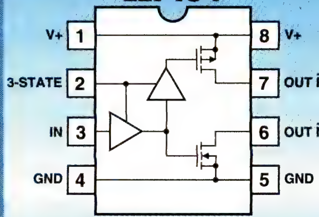


Complementary

- 20 ns Prop Delay
- 20 ns Switch. Time
- $1.96 – 100's P-DIP

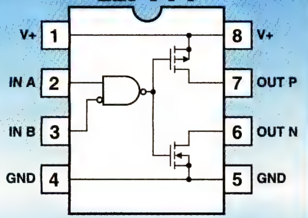
3-State Line Driver/Dual Input Line Driver, 4.0 Amps Output

EL7134



- 20 ns Prop Delay
- 20 ns Switching Time
- $2.40 – 100's P-DIP

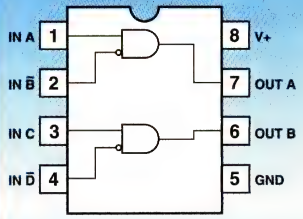
EL7144



- 20 ns Prop Delay
- 20 ns Switching Time
- $2.40 – 100's P-DIP

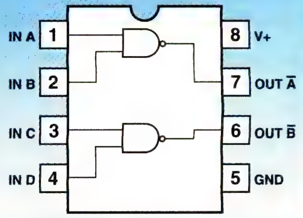
Dual Channel/Dual Input, 2.0 Amps

EL7242



- 20 ns Prop Delay
- 20 ns Switching Time
- $2.25 – 100's P-DIP

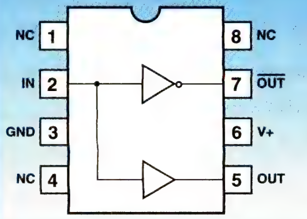
EL7252



- 20 ns Prop Delay
- 20 ns Switching Time
- $2.25 – 100's P-DIP

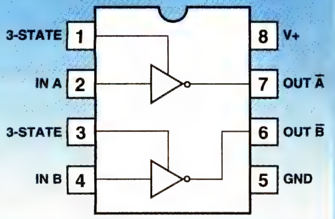
CCD Driver/Dual Channel 3-State Line Driver

EL7182



- Reduced Clock Skew
- 20 ns Switching Time
- $2.65 – 100's P-DIP

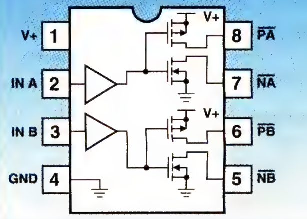
EL7232



- 20 ns Prop Delay
- 20 ns Switching Time
- $2.25 – 100's P-DIP

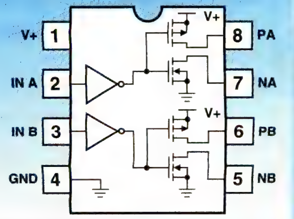
Dual Channel – Isolated Drains, 2.0 Amps

EL7262



- 20 ns Prop Delay
- 20 ns Switching Time
- $2.25 – 100's P-DIP

EL7272



- 20 ns Prop Delay
- 20 ns Switching Time
- $2.25 – 100's P-DIP

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CIRCLE 96 FOR U.S. RESPONSE CIRCLE 97 FOR RESPONSE OUTSIDE THE U.S.

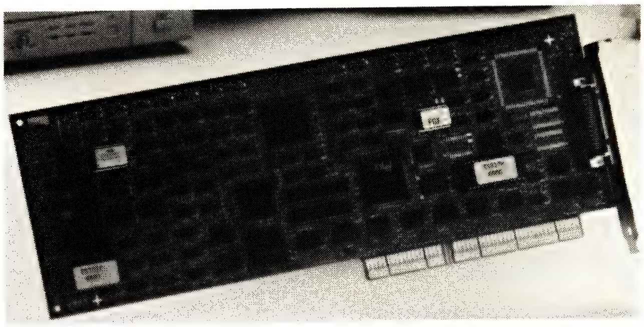
A DESIGNER'S GUIDE TO COMPUTER BUSES

As computer-product life cycles continue to evaporate, they require that most of the related components adhere to the same shrinking schedule. This includes microprocessors, disk drives, memory architectures, and so forth. Computer buses, on the other hand, seem to buck that trend, living long, healthy lives. For example, the ISA bus, probably the most popular in terms of installed base, has been around for over ten years. The VMEbus recently celebrated a decade of service as well. And Multibus I and the STD bus were introduced in the 1970s, eons ago when measured in computer years. While these old-reliable buses have been tweaked to increase performance, their overall architectures remain basically unchanged.

To help designers who build systems, components, and boards using the industry's popular system buses and interfaces, both new and old, we've compiled information pertaining to each bus. These include the Extended Industry Standard Architecture (EISA) bus, Fibre Channel, Futurebus+, the Industry Standard Architecture (ISA), MBus, the Micro Channel Architecture (MCA), Multibus I, Multibus II, NuBus, the Peripheral Component Interconnect (PCI) bus, SBus, the Small Computer Systems Interface (SCSI), the STD bus, the STD 32 bus, TurboChannel, the VESA local bus (VL-Bus), and VMEbus. While we couldn't possibly publish every detail about each bus, we have outlined the most vital information.

The boards pictured are at about one-fourth of their actual size.

BY RICHARD NASS



▶ EXTENDED INDUSTRY STANDARD ARCHITECTURE (EISA)

TECHNICAL CHARACTERISTICS

Speed: 8.33 MHz
Transfer rate: 8.33 Mbytes/s or 33 Mbytes/s in burst mode
Board size: About 63 in.^{2}
Connector: Contains a two-tier edge connector: the upper tier connects to the ISA bus signals; the lower tier connects to the EISA extension signals
Maximum number of slots: Logical limit is 15 slots, but the system-board electrical characteristics and EISA chip-set capabilities usually dictate a lower limit
Bus width: four 8-bit data paths
Other: DMA and bus-master support

APPLICATIONS

Mainstream computing and file servers

HISTORY

EISA grew out of a rebellion against IBM's switch to its proprietary Micro Channel Architecture (MCA), in November 1989. EISA proponents, or the "gang of nine" as they were referred to at the time, formed the EISA consortium and generated the EISA specification as an open alternative to MCA.

SUPPORTING GROUP

The Institute of Electrical and Electronic Engineers (IEEE)

MAJOR INDUSTRY FORCES

AST Research, Compaq, Epson, Hewlett-Packard, NEC, Olivetti, Tandy, Wyse, Zenith

▶ FIBRE CHANNEL SERIAL INTERFACE

TECHNICAL CHARACTERISTICS

Speed: Ranges from 133 to 1065 Mbaud; transfer rate ranges from 12.5 to 100 Mbytes/s
Board size: Not applicable
Connector: Several types, depending on application
Maximum number of slots: One device at each end of connection (a point-to-point architecture)
Other: Fibre Channel protocols match SCSI protocols

APPLICATIONS

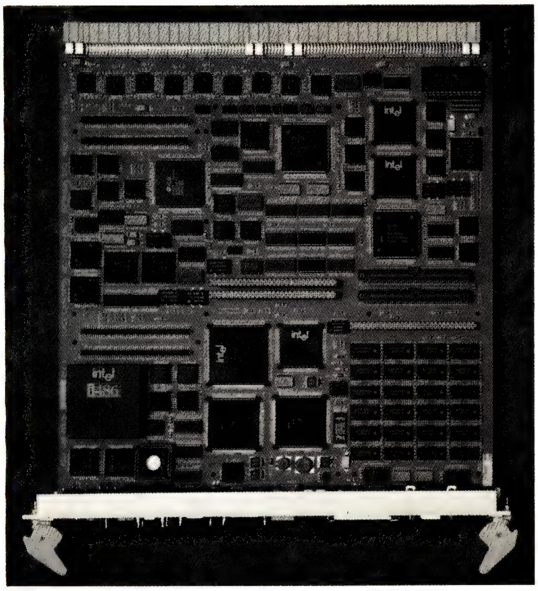
Peripheral-device attachment (disks to hosts), host-to-host communications, specialized networking (to transfer large blocks of data)

HISTORY

Started in 1989 to create a low-cost, yet high-performance, channel as a replacement to SCSI. It was developed by AMD, IBM, STC, and the Defense Industry Labs.

SUPPORTING GROUPS
The Fibre Channel Systems Initiative, the Fibre Channel Association

MAJOR INDUSTRY FORCES
Amdahl, Hewlett-Packard, IBM, Sun Microsystems, Tandem, Unisys



▶ FUTUREBUS+

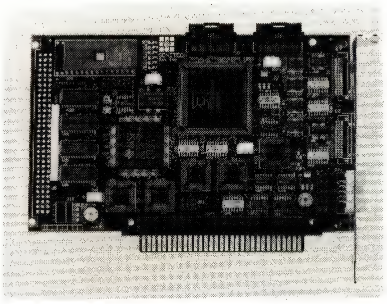
TECHNICAL CHARACTERISTICS
Speed: Processor dependent, not limited by the standard or tied to a specific technology
Transfer rate: 3.2 Gbytes/s at 256 bits
Board size: 6U, 10U, and 12U
Connector: Many types, depending on profile; supplied by AMP, Amphenol, BICC-VERO, ITT Canon, and others
Maximum number of slots: 14
Bus width: 32 to 256 bits
Other: Supports SBus and PCI as mezzanine buses, offers seven profiles that are differentiated by application

APPLICATIONS
Telecommunications, data communications, military

HISTORY
Revision of original Futurebus specification (IEEE 896.1-1987). Formally announced by VITA in December 1988. Selected as architecture of choice by U.S. Navy.

SUPPORTING GROUP
VITA (VFEA International Trade Association),
phone: (602) 951-8866

MAJOR INDUSTRY FORCES
AEON, AMP, Amphenol, BICC-VERO, Cable & Computer, Digital Equipment, Force, Genroco, Hybricon, ITT Canon, Mupac, Nanotek, National Semiconductor, Newbridge, Schroff, Signetics, Technobox, Texas Instruments, VMetro



▶ INDUSTRY STANDARD ARCHITECTURE (ISA)

TECHNICAL CHARACTERISTICS
Speed: 8 MHz (or 8.33 MHz)
Transfer rate: 8.33 Mbytes/s
Board size: About 63 in.^{2}
Connector: Two types, 8 and 16 bits: the 8-bit connector is backward-compatible with the IBM PC and XT bus; the 16-bit connector is an 8-bit connector with a 16-bit extension to supply the expanded signals (data and address lines, interrupt requests, DMA channels, etc.)
Maximum number of slots: Defined by the electrical characteristics of the system board and the power-supply drive capability
Bus width: Two 8-bit data paths
Other: Support for DMA block transfers between memory and I/O; maximum DMA-transfer rate is 2 Mbytes/s

APPLICATIONS
Mainstream computing

HISTORY
The 8-MHz ISA bus was developed by IBM, but the specifications weren't published until a few years after introduction. As a result, companies had to form their own version of the specification, which explains the many incompatibility problems that exist on the ISA bus.

SUPPORTING GROUP
The Institute of Electrical and Electronic Engineers (IEEE)

MAJOR INDUSTRY FORCES
Compaq, Dell Computer, IBM, and many others

▶ MBUS

TECHNICAL CHARACTERISTICS
Speed: 40 MHz (50 MHz soon)
Transfer rate: 320 Mbytes/s in burst mode;
200 Mbytes/s sustained
Board size: 3.3 by 2.79 in. or 3.3 by 5.776 in.
Connector: 100 pins (AMP Microstrip 121354-4)
Maximum number of slots: 6 theoretically; 4 in practice
Bus width: 64 bits; address and data multiplexed
Other: Message passing supported; standard bus-interface ICs available; support for mezzanine buses

APPLICATIONS
Plug-in processor modules for workstations and servers

HISTORY
Designed by a group of Sparc vendors in 1989-1990. First

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TECHNOLOGY

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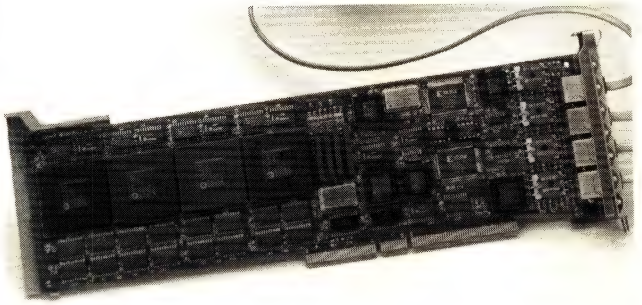
shipped in Sun Microsystems products in 1991. Texas Instruments, Cypress, and LSI Logic have shipped MBus components.

SUPPORTING GROUP
Sparc International, phone: (415) 321-8692

MAJOR INDUSTRY FORCES
Sun Microsystems, Texas Instruments



▶ MICRO CHANNEL ARCHITECTURE (MCA)

TECHNICAL CHARACTERISTICS

Speed: 10 to 20 MHz
Transfer rate: 157 Mbytes/s in burst mode; 76 Mbytes/s sustained
Board size: From 3.475 by 6.299 in. to 9 by 13 in.
Connector: 50-mil connector with 112 to 182 pins
Maximum number of slots: 15
Bus width: Currently 16 and 32 bits; 64 bits planned

APPLICATIONS
Most add-in board functions in desktop systems, workstations, and file servers

HISTORY
Developed in 1987 by IBM in conjunction with the company's PS/2 line of computers.

SUPPORTING GROUP
Micro Channel Developers Association,
phone: (916) 222-2262

MAJOR INDUSTRY FORCES
ALR, AMD, AMP, Ancot, Aox, ATTO Technology, Future Domain, Hitachi, IBM, Motorola, National Instruments, NCR, Phoenix Technologies, Sharp, Stratus Computer

▶ MULTIBUS I

TECHNICAL CHARACTERISTICS

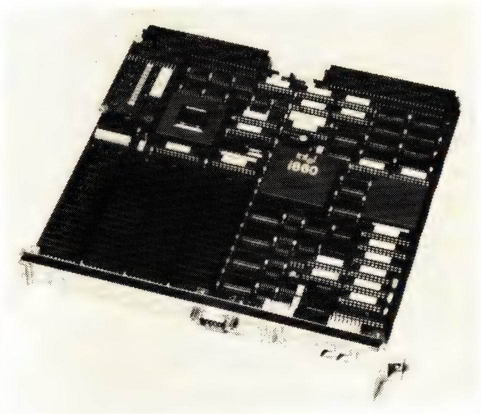
Speed: Processor-dependent
Transfer rate: 6 to 12 Mbytes/s
Board size: 6.2 by 11.75 in.
Connector: Two edge connectors
Maximum number of slots: 15
Bus width: 16 bits
Other: Support for mezzanine buses and DIN connectors

APPLICATIONS
Industrial automation and machine control, data communications, medical, and military

HISTORY
Introduced in 1977. Became an IEEE-approved standard in 1982. Installed base of about 2.5 million.

SUPPORTING GROUP
Multibus Manufacturers Group (MMG),
phone: (503) 696-7155

MAJOR INDUSTRY FORCES
Central Data, Intel, SBE, Siemens



▶ MULTIBUS II

TECHNICAL CHARACTERISTICS

Speed: Processor-dependent
Transfer rate: 80 Mbytes/s in burst mode; 64 Mbytes/s sustained at 20 MHz.
Board size: 9.2 by 8.7 in. (233 by 220 mm)
Connector: 96-pin DIN type; second DIN type available for user applications
Maximum number of slots: 21
Bus width: 32 bits
Other: Message passing supported; standard bus-interface ICs available; support for mezzanine buses

APPLICATIONS
Telecommunications, industrial automation and machine control, data communications, medical, and military

HISTORY
Introduced in 1985, then became an IEEE-approved standard in 1987. Has grown to support some 160 vendors in 1993.

SUPPORTING GROUP
Multibus Manufacturers Group (MMG),
phone: (503) 696-7155

MAJOR INDUSTRY FORCES
CCT, Intel, Mentec Computer Systems, Micro Industries, Siemens

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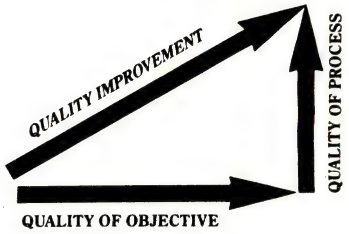

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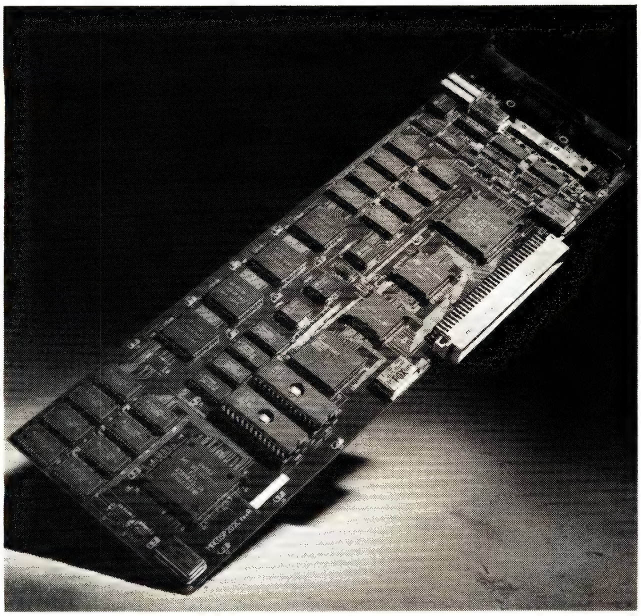
CIRCLE 211 FOR U.S. RESPONSE

CIRCLE 212 FOR RESPONSE OUTSIDE THE U.S.



▶ NUBUS

TECHNICAL CHARACTERISTICS

Speed: 10 MHz
Transfer rate: 40 Mbytes/s
Board size: 4 by 12.875 in., or 11 by 14.4 in.
Connector: 96-pin DIN
Bus width: 32 bits
Other: Simple master-slave architecture; I/Os and interrupts are memory mapped

APPLICATIONS

Mainstream desktop computing, from low-end desktops to high-performance multiprocessor systems

HISTORY

Originally conceived at the Massachusetts Institute of Technology (MIT) in late 1970s. First NuBus system was produced by Western Digital in 1981. Texas Instruments became involved in early 1983. The NuBus became a standard of the IEEE in 1987. The specification was refined by Apple Computer and is employed in Apple's Macintosh family of desktop computers, starting in 1987.

SUPPORTING GROUPS

The Institute of Electrical and Electronic Engineers (IEEE), NuBus Manufacturers and User Group (NuGroup)

MAJOR INDUSTRY FORCES

Apple Computer, Texas Instruments

▶ PERIPHERAL COMPONENT INTERCONNECT (PCI)

TECHNICAL CHARACTERISTICS

Speed: Up to 33 MHz
Transfer rate: 132 Mbytes/s maximum at 32 bits; 264 Mbytes/s maximum at 64 bits
Board size: ISA, EISA, or Micro Channel form factor
Connector: Micro Channel type: 120 pins for 32 bits, 184 pins for 64 bits
Maximum number of slots: 10 loads, typically 2 to 3 add-in cards and 3 to 4 motherboard devices
Bus width: 32 or 64 bits

APPLICATIONS

Most add-in card functions in portables, desktops, workstations, and servers

HISTORY

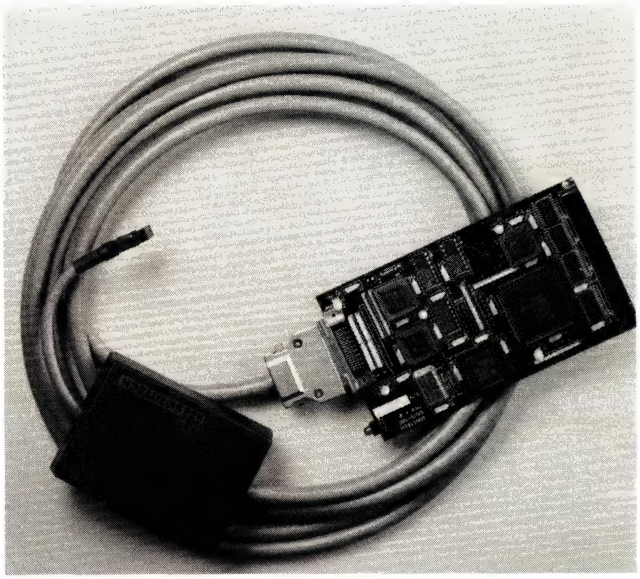
Proposed by Intel in December 1991. Component standard announced in June 1992. Connector standard proposed in October 1992. Complete specification (Rev. 2.0) released in May 1993.

SUPPORTING GROUP

PCI Special Interest Group (PCI SIG),
phone: (503) 696-2000

MAJOR INDUSTRY FORCES

Adaptec, AMD, ATI Technologies, Compaq, Digital Equipment, IBM, Intel, National Semiconductor, NCR



▶ SBUS

TECHNICAL CHARACTERISTICS

Speed: 20 to 25 MHz
Transfer rate: 80 Mbytes/s theoretically at 32 bits, and 168 Mbytes/s theoretically at 64 bits
Board size: 83.83 by 146.7 mm
Connector: 96 pins, available from AMP
Maximum number of slots: Limited by capacitance and line length
Bus width: 32 or 64 bits
Other: Virtual-to-real address translations are done automatically; has retry and error capability

APPLICATIONS

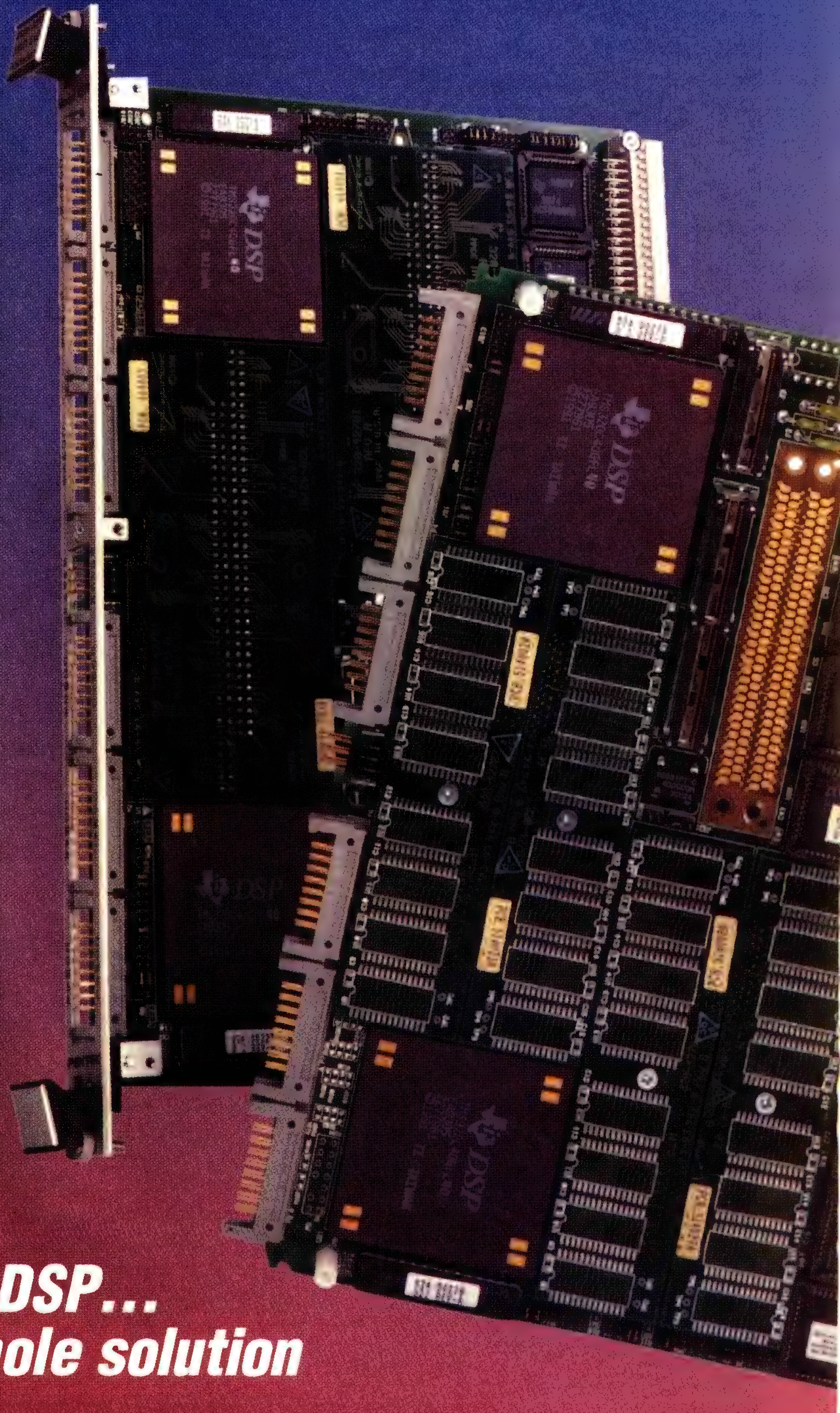
I/O for workstations and servers

HISTORY

Developed by Sun Microsystems in 1989 and is included in the company's popular Sparcstation line of workstations.

Pentek Quad 'C40 VME

There are other Quad 'C40 VME boards. They don't come with half the I/O, software, and DSP experience as the Pentek 4270.



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ALACRON i860 VME

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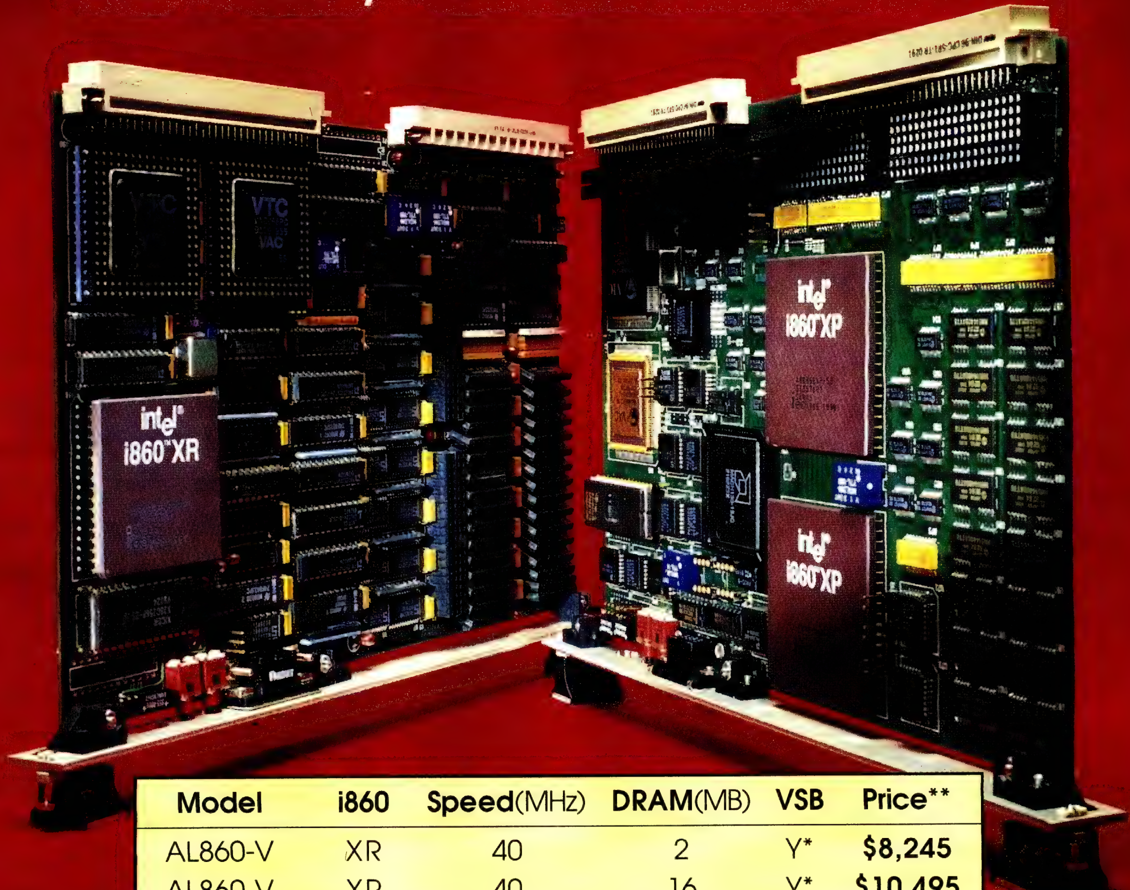

Model	i860	Speed(MHz)	DRAM(MB)	VSB	Price**
AL860-V	XR	40	2	Y*	**$8,245**
AL860-V	XR	40	16	Y*	**$10,495**
FT*200*/1-V	XP	50	16	Y*	**$12,290**
FT*200*/2-V	dualXP	50	16	Y*	**$15,290**

ALACRON i860 VME Beats the Competition Hands Down

ALACRON VME boards are supported by a complete software development environment including DSP library routines capable of executing a 1K complex FFT in under 300 microseconds on the dual 50MHz FT*200* series.

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ALACRON

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Phone: (603) 891-2750 • Fax: (603) 891-2745

All product information is accurate as of January 1993. *VSB daughter board option included in price.
**Suggested list price effective January 1993. Trademarks are property of their respective owners.

CIRCLE 82 FOR U.S. RESPONSE

CIRCLE 83 FOR RESPONSE OUTSIDE THE U.S.

Over 135 manufacturers supply over 350 different SBus I/O cards. Adopted by the IEEE in June 1993 as standard 1496-1993.

SUPPORTING GROUP
The Institute of Electrical and Electronic Engineers (IEEE)

MAJOR INDUSTRY FORCES
Sun Microsystems, Force Computers

▶ SMALL COMPUTER SYSTEMS INTERFACE 2 (SCSI 2)

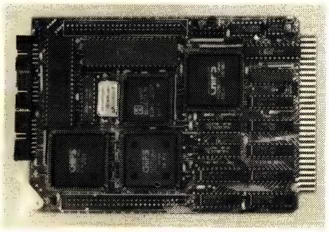
TECHNICAL CHARACTERISTICS
Speed: 5 MHz in asynchronous mode and 10 MHz in synchronous mode (for fast SCSI)
Transfer rate: 10 Mbytes/s for fast SCSI 2 and 20 Mbytes/s for fast and wide SCSI 2
Board size: Not applicable
Connector: ANSI standard; 50 pins or 68 pins for fast and wide SCSI 2
Maximum number of slots: Seven devices per host adapter (16-bit SCSI can have 15 devices)
Bus width: Up to 32 bits
Other: 16 μs is the theoretical overhead; peer-to-peer setup (hosts can talk to peripherals or other hosts)

APPLICATIONS
Most high-end disk and tape drives

HISTORY
Began as the Shugart Associates System Interface (SASI) and evolved into SCSI in 1982. Became a standard of the American National Standards Institute (ANSI) in 1986. SCSI 2 work began in 1988. Components for fast and wide SCSI-2 appeared in 1991.

SUPPORTING GROUP
American National Standards Institute (ANSI)

MAJOR INDUSTRY FORCES
Adaptec, BusLogic, Emulex, Future Domain, and NCR, as well as most major disk- and tape-drive makers



▶ STDBUS

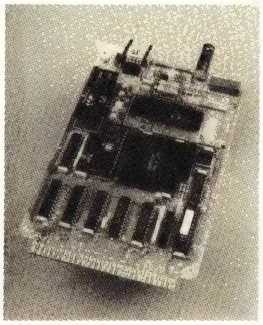
TECHNICAL CHARACTERISTICS
Speed: 8 MHz
Transfer rate: 2 Mbytes/s
Board size: 4.5 by 6.5 in.
Connector: 56-pin card edge type
Maximum number of slots: Typically 24
Bus width: 8 bits (or 16 bits in some incompatible configurations)

APPLICATIONS
Equipment control, data acquisition, and system monitoring

HISTORY
Initially developed as an 8-bit control bus by Mostek and Pro-Log in the mid 1970s. Originally, STD-bus products were populated with 8-bit microprocessors, such as a Z80 and 8085. The STD-8088 specification, defined in 1983, allowed the bus to use 80XXX-type Intel CPUs, enabling the use of DOS-based applications.

SUPPORTING GROUP
STD Manufacturers Group (STDMG),
phone: (408) 723-5083

MAJOR INDUSTRY FORCES
MicroSys, Pro-Log, Systek, VersaLogic, WinSystems, Ziatech



▶ STD 32

TECHNICAL CHARACTERISTICS
Speed: 8 MHz
Transfer rate: 32 Mbytes/s
Board size: 4.5 by 6.5 in.
Connector: 136-pin card edge
Maximum number of slots: Typically 24
Bus width: 32 bits
Other: Permanent master/temporary master multiprotocol, dynamic bus sizing, direct memory access, and slot-specific interrupts

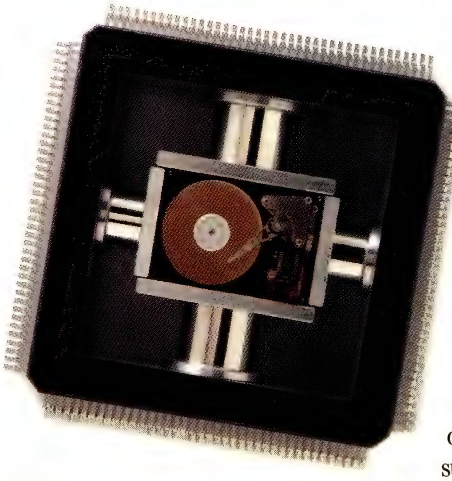
APPLICATIONS
Equipment control, data acquisition, system monitoring, simulation, and imaging

HISTORY
Developed by Ziatech as an extension to the original 8-bit STD bus. STD 32 is a 32-bit bus that's backward-compatible with existing STD-8088 (8-bit) products.

SUPPORTING GROUPS
STD Manufacturers Group (STDMG), phone: (408) 723-5083;STD 32 Special Interest Group (SIG 32),
phone: (310) 477-9664

MAJOR INDUSTRY FORCES
Apix, Kinetic Computers, Motion Engineering, VersaLogic, Ziatech

Improve yo



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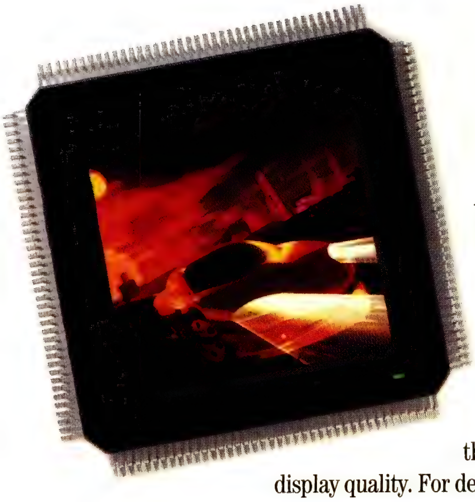

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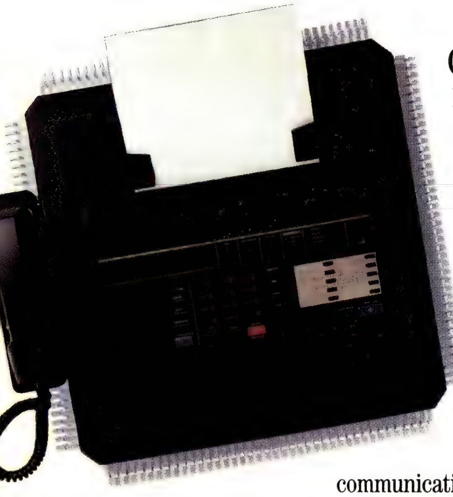

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For innovation, call on our broad line of datacom and telecom products…all of them complete with full software support to ease your design-in effort. For example, our recently announced highly integrated fax/data modem chip set brings high-quality voice answering machine capabilities to your PCs. For data networking, we feature serial I/O and LAN controllers. And our SmartAnalog™ interface circuits from Crystal Semiconductor help your designs tap into the vast telecommunications world at a price/performance point that's just right.

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COMPUTINGBUS GUIDE

▶ TURBOCHANNEL

TECHNICAL CHARACTERISTICS

Speed: Any fixed frequency from 12.5 to 25 MHz
Transfer rate: 50 to 98 Mbytes/s
Board size: 5.475 by 4.4 in. (single slot); 5.475 by 9.1 in. (double slot); or 5.475 by 13.8 in. (triple slot)
Connector: 98-pin DIN type (AMP 532504-1 and 532523-1)
Maximum number of slots: 2 to 6
Bus width: 32 bits
Other: TurboChannel is a synchronous, asymmetrical I/O channel with two transaction types—I/O and direct memory access; each slot has a system-specific 4-to-512-Mbyte address range for I/O transactions

APPLICATIONS

Ranging from high-performance graphics adapters to low-speed serial communications ports

HISTORY

Introduced in 1989 on the Digital Equipment Corp.'s (DEC's) DECStation 5000-200 workstation, and is currently DEC's workstation I/O bus. Will also be supported on DEC's Alpha-based workstations

SUPPORTING GROUPS

No industry consortia

MAJOR INDUSTRY FORCES

Digital Equipment Corp.

▶ VESA LOCAL BUS (VL-BUS)

TECHNICAL CHARACTERISTICS

Speed: Up to 66 MHz
Transfer rate: Theoretical bandwidth of 160 Mbytes/s at 32 bits and 267 Mbytes/s at 64 bits, both at 50 MHz
Board size: ISA, EISA, or Micro Channel form factor
Connector: Micro Channel type; 116 pins for both 32 and 64 bits
Maximum number of slots: 3
Bus width: 32 or 64 bits of data with a 32-bit address
Other: Transparent to software; doesn't affect performance of host bus

APPLICATIONS

Most add-in card functions in portables, desktops, workstations, and servers, although graphics controllers are currently the most popular

HISTORY

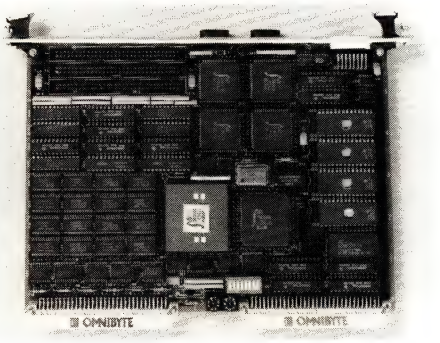
Proposal for VL-bus began in late 1991. Version 1.0 was released in August 1992. Version 2.0 is in the final review stage. It adds the 64-bit capability and support for CPUs with a write-back cache memory.

SUPPORTING GROUP

The Video Electronics Standards Association (VESA), phone: (408) 435-0333

MAJOR INDUSTRY FORCES

Numerous PC vendors, peripheral manufacturers, and software developers



▶ VMEBUS

TECHNICAL CHARACTERISTICS

Transfer rate: 40 Mbytes/s, or 80 Mbytes/s using VME64
Board size: 6.3 by 3.9 in. (233 by 220 mm) for 3U form factor or 6.3 by 9.2 in. (160 by 233 mm) for 6U form factor
Connector: 64 or 96 pins
Maximum number of slots: 21
Bus width: 32 bits (or 64 bits for VME64)
Other: Standard bus-interface ICs available; support for mezzanine buses

APPLICATIONS

Communications, industrial automation, data acquisition and control, military, manufacturing and process control, office automation, test and measurement, simulation, imaging, and graphics

HISTORY

Formally announced in 1981 by Mostek, Motorola, Signetics/Philips, and Thompson CSF. First boards were produced in 1982. VITA, the VMEbus trade association, was formed in 1984. Became a standard of the IEEE (standard 1014-1987) in 1987. VME64 was proposed in 1989. There are currently over 280 vendors of VMEbus manufacturers that combined carry over 4500 products.

SUPPORTING GROUP

VITA (VFEA International Trade Association), phone: (602) 951-8866

MAJOR INDUSTRY FORCES

DY-4, Eltec, Force Computers, Interphase, Motorola, PEP Modular Computers, Radstone, Rockwell CMC, Themis

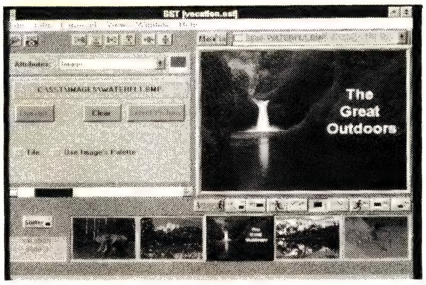
Electronic Design would like to thank the following companies and trade associations for their help in compiling this information: Apple Computer, Digital Equipment, Micro Channel Developers Association, Mind Share, Motorola, Multibus Manufacturers Group, National Semiconductor, PCI Special Interest Group, Sun Microsystems, the Video Electronics Standards Association, and Ziatech.

ARRAY FAMILY, TOOLS, BOOST CHIP EFFICIENCY

Offering a suite of design tools, a design library, and a new family of high-efficiency gate arrays, Aspec Technology in conjunction with Samsung Semiconductor and Sanyo is giving designers an improved ASIC alternative to existing gate arrays. Though the family of 19 different masterslice arrays was defined by Aspec, Samsung and Sanyo will both manufacture and market the gate array masterslices, while Aspec will look for licensing opportunities for its cell library, design tools, and array architecture. The array family contains base chips with gate capacities from 11,712 to over 500,000 gates, and estimated gate utilizations of 5856 to just over 200,000 gates.

The arrays will be fabricated by Samsung and Sanyo on 0.8-μm two-metal, CMOS processes that yield typical internal gate delays of 325 ns and power dissipations of less than 5 μW/gate/MHz. Both 5- and 3-V versions of the arrays are available. The masterslices offer from 68 to 440 signal I/O pads (84 to 456 total pads) and can drive up to 24 mA on any output buffer. Although there are several other high-gate-count array families, designers at Aspec expect their chips to deliver 27% denser circuits, compared with most other gate array choices.

The improvement in density is the result of a proprietary cell architecture that improves cell density and routability. As a result, smaller chips can hold circuits that would otherwise have required higher-gate-count arrays from other vendors. Conversely, the same capacity chip as competitive arrays could offer can hold a more-complex design. This results in lowering the typical cost of a solution based on the Aspec architecture.



To simplify the circuit implementation, Aspec's Portfolio Design Library and tools provide a wide range building-block cells and larger macro/megacells, as well as compiled blocks such as RAMs or ROMs. Aspec will license the library, design tools, and array architecture for the masterslices for $250,000. The libraries and tools run on most commercial CAD systems. Array prices depend on complexity, packaging, and quantity, but a typical design would cost about 20 millicents/gate when the array is housed in a 160-lead PQFP and ordered in lots of 20,000 to 30,000 units.

***Aspec Technology Inc.**, 3901 Burton Drive, Santa Clara, CA 95054; Conrad Dell'Oca, (408) 988-4411.* **CIRCLE 620**

***Samsung Semiconductor Corp.**, 3655 N. First Street, San Jose, CA 95134-1713; Josh Bellin, (408) 954-6925.* **CIRCLE 621**

■ *DAVE BURSKY*

0.8 μM ASIC MACROS ADD UART, SCSI, RTC

Providing designers with universal asynchronous receiver transmitters, small-computer system interfaces, and real-time clocks, several hard macrocells join Oki Semiconductor's 0.8-μm design libraries. In the UART series, the Z450 is the simplest, performing serial-to-parallel or parallel-to-serial conversion and providing error information such as parity and overrun. The similar Z550 also includes 16-byte FIFO buffers on both the transmitter and receiver. The Z452 is a dual-channel version of the Z450 with a full bidirectional Centronics-compatible parallel port. The Z390 SCSI macrocell is equivalent to the 53C90 SCSI-2 controller chip and performs asynchronous transfers at 5 Mbytes/s. Supporting the controller in the library are high-current (48 mA) SCSI-compatible I/O cells. Providing a time-of-day clock, a 100-year calendar, a programmable periodic interrupt, and a square-wave generator, the Z818 RTC macrocell fits a wide range of personal computing and industrial applications and is compatible with the MC146818 RTC chip. It includes 114 bytes of RAM that can be used for independent storage needs with a battery backup. All UARTs and the RTC can be used in 3- or 5-V ASIC designs; the current SCSI cell is only characterized for 5-V operation. DB

Oki Semiconductor, 785 N. Mary Ave., Sunnyvale, CA 94086; Steve Lapham, (408) 720-1900. **CIRCLE 622**

QUAD-PORT REPEATER AIDS ETHERNET SWITCHES

Simplifying the design of switching hubs for Ethernet-based networks, the T7204 quad single-port repeater provides four twisted-pair or four attachment unit interface ports that can each be independently configured. On the host side, the chip has a microprocessor interface for control and access to status and configuration registers. The chip also includes a full MAC (media access controller) interface port and a packet post-processor and event counters for statistics reporting. Each port includes an on-chip receiver with squelch and receive logic, including link-integrity test and automatic polarity reversal detection and correction options. Most of the transmit logic, including pre-equalization and link-pulse generation, is on the chip. The repeater chip uses a backplane interface that provides either an NRZ (non-return to zero) port for circuit switching, or a MAC port for packet switching. Per-port segmentation improves network management by enabling the network administrator to better balance traffic loads, set aside segments for redundancy and reliability, and reduce the cost of moves and rearrangements. Housed in a 132-lead PQFP, the CMOS T7204 costs $36 each in lots of 25,000. DB

AT&T Microelectronics, Dept. AL-500404200, 555 Union Blvd., Allentown, PA 18103; John Bestel, (215) 778-4106. **CIRCLE 623**

PLUG MEMORY CARDS INTO STDBUS

As a floppy-disk drive alternative, the MCM-RSSD-J removable solid-state disk drive is suited for harsh environments where the computer systems are subjected to extended temperatures, magnetic fields, vibration, etc. The drive contains no moving parts. It fits an STDbus configuration and is fully compliant with the JEIDA memory-card standards. It's compatible with industry-standard 68-pin PCMCIA cards and supports SRAM, OTPROM, EEPROM, and flash memory cartridges, up to 64 Mbytes. The MCM-RSSD-J contains status LEDs on the front panel which indicate low battery and busy. The drive appears to the system as a standard IDE interface. It sells for $395. A CMOS version costs $425. RN

WinSystems Inc., 715 Stadium Dr., Arlington, TX 76011; (817) 274-7553. **CIRCLE 624**

MONITORS FEATURE POWER-DOWN MODE

A family of monitors which meet the guidelines for the EPA Energy Star program for power efficiency all boast high resolution, an ergonomic design, and touch-screen capabilities. The 14V and 15V (14- and 15-in.) models power-down to 30 W in the sleep mode, while the 14P and 15P consume just 8 W. On-board memory can store up to 26 screen modes, eleven of which are user definable, and recall them each time particular applications are run. Setting storage is done automatically. The 14P and 15P can be turned into touch-screen displays by adding a capacitive overlay. Prices range from $520 for the 14V to $1593 for the 15P with touch-screen capabilities. A lift-tilt-swivel stand costs $120. RN

IBM Corp., 1133 Westchester Ave., White Plains, NY 10604. **CIRCLE 625**

FAST
Amps & Buffers

- Bandwidth (GBP) 100 MHz > < 1 GHz
- Slew Rate 1000 > < 7000 V/µs

Calogic's fast op amps and buffers offer the best of both worlds, pin for pin replacements to industry standard devices as well as more efficient and wider bandwidth devices.

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Part No.	S/R (V/µs)	SS BW (MHz)	I_{OUT} (mA)	Price ($)*
CLM4121	4000	180	200	1.95
CLM4125	3500	300	80	1.95
CLM4102	3000	200	160	1.85
LH4002	2500	200	60	3.75
CA2003	1200	50	200	1.65
CA2033	1200	50	200	1.65
LM6121	1200	50	200	1.89
LH4001	200	30	100	2.75
LH0002	200	30	100	2.75

FET Input Buffers

Part No.	S/R (V/µs)	SS BW (MHz)	I_{OUT} (mA)	Price ($)*
CLM4109	7000	250	250	4.95
CLM4163	6000	150	1000	4.95
CLM4133	4000	200	150	3.25
LH0033	1500	100	150	9.75

Fast Op Amps

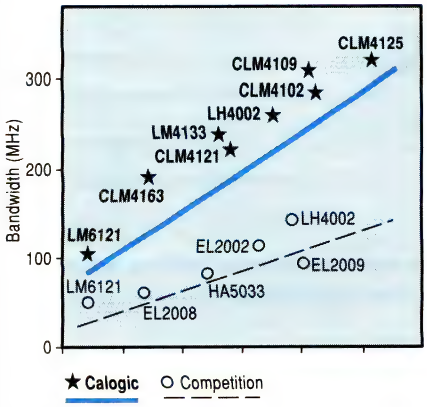
Part No.	I Bias (µA)	V_{OS} (mV)	S/R (V/µs)	SS BW (MHz)	Price ($)*
CLM6181	5/1.5	5	1400	100	2.99
CLM4132	200pA	5	650	150	6.85
CLM4124	10	5	500	100	3.75
CLM4152	200pA	5	500	100	10.50
CA2020	40/15	10	300	50	3.53
LH0032	200pA	5	500	100	10.50

General Op Amps

Part No.	I Bias (µA)	V_{OS} (µV)	S/R (V/µs)	SS BW (MHz)	Price ($)*
OP-07	4nA	75	0.3	1	1.43
OP-27	40nA	25	2.8	1	2.29
OP-77	2	25	0.3	1	0.80

Price per "N" package style *100 piece quantity

Compare the Performance:



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CIRCLE 217 FOR U.S. RESPONSE
CIRCLE 218 FOR RESPONSE OUTSIDE THE U.S.

MONITOR MEASURES E-FIELDS TO 40 GHZ

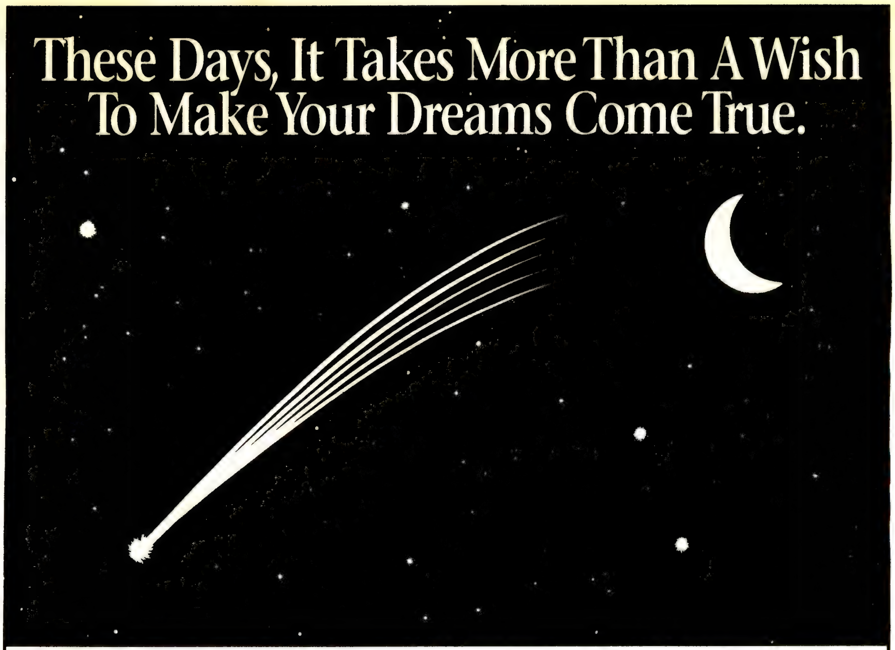
A solid-state system for RF susceptability testing can measure and level electric fields as high as 300 V/m in a range of 10 kHz to 40 GHz. The system is based on the FM2000 four-slot monitor mainframe. The monitor accepts up to four E-field-level signals from either FP2000 (10 kHz to 1 GHz) or FP2080 (80 MHz to 40 GHz) remote probes. The probes come with 10-m two-way fiberoptic cables. The operator can select high, low, or average readings from either multiple or individual probes, with the results shown on an LED display. Outputs are sent to IEEE-488 and RS-232 interfaces and to two 0-to-4-V dc analog control circuits. The FM2000 costs $6500, the FP2000 $5200, and the FP2080 $11,000. An adjustable probe stand costs $200. Delivery is from stock. JN

Amplifier Research, 160 School House, Rd., Souderton, PA 18964-9990; (800) 933-8181 or (215) 723-8181. **CIRCLE 626**

TOOLS AID IN TESTING OF COMPLEX ASICS

ViewTest, a tool suite for automating the generation of efficient and compact manufacturing test programs for ASICs, works with sequential as well combinational logic. The tools handle synchronous or asynchronous circuits, ASICs and full-custom ICs, and low- or high-complexity chips, including those with embedded functions such as RAM. Functions available within ViewTest include testability analysis, design rule checking, automatic test pattern generation (ATPG), fault simulation, test synthesis, vector compaction, I_{DDQ} test generation, and ASIC vendor interface kits. Sequential ATPG algorithms and heuristics eliminate the typical test constraints designers face. ViewTest prices start at $75,000 for a complete system. JN

Viewlogic Systems Inc., 293 Boston Post Rd. West, Marlboro, MA 01752-4615; (508) 480-0881. **CIRCLE 627**



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THE DEPARTMENT OF THE TREASURY 1789

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Real-time Multi-tasking
For MS-DOS and Embedded Systems

The Tics Realtime multi-tasking kernel is a linkable C library that allows C functions to run as preemptive concurrent tasks. Developed for professional software developers who need a capable full-featured real-time multi-tasking development system. Tics can run with MS-DOS or stand-alone on an embedded micro-processor. Turn your MS-DOS based PC into a powerful real-time multi-tasking system. This complete development system includes the multi-tasking kernel library, memory management, a multi-tasking COM port library, and comprehensive sample programs for multi-tasking dials and gauges, data acquisition and control, and more. No royalties. Full C source code for the entire system is included. Call today for details.

- C source code is included - fully documented and complete.
- Includes our new book "The Art of Real-time Programming".
- Tics is written entirely in C and is portable to virtually any microprocessor.
- Tics can run with MS-DOS or stand-alone on an embedded target.
- The PC timer chip is reprogrammed to user specified granularity.
- Includes multi-taking COM port library for multi-tasking serial IO.
- Preemptive, cooperative, or time-sliced scheduling, configurable on a task by task basis.
- No restriction on the number of tasks.
- Stack size is variable on a task by task basis.
- Priorities can be changed dynamically.
- Tasks may be created dynamically.
- The development system also includes Tiny Tics, a small round robin kernel that is ideal for micro-controllers.
- Requires about 8K bytes of code space & is ROMable.
- Three types of high speed timers: in-line pause, one-shot timers, and time critical periodic timers.
- Differential timer management system.
- Inter-task communication using message queues or high speed mailboxes.
- Critical region management.
- High speed memory management system. Unrestricted number of memory pools.
- Priorities on tasks and messages provide great flexibility. Priorities on messages means that high priority messages go straight to the front of the queue.
- Optionally, cooperative tasks may share a common stack so that hundreds of tasks can run with the overhead of a single stack.
- Object oriented. Create task instances with their own separate instance data.
- Messages or mail can be sent from within an isr.
- Time out option while waiting for a message.
- Message and timer cancellation. A message or timer is cancelled even after it has been dispatched.
- Dynamic stack checking option checks for stack pointer integrity on each context switch.

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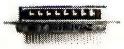
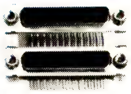
CIRCLE 179 FOR U.S. RESPONSE
CIRCLE 180 FOR RESPONSE OUTSIDE THE U.S.

FREEDOM
FROM EMI/RFI NOISE PROBLEMS

Filtered, flat cable type; IDC, male connectors; 9-37 position available.

Filtered solder cup termination; standard size D-subs; 9-50 position; male or female.


Filtered, pc tail, termination direct pc mount; standard size D-subs; 9-50 position; male and female.


Filtered dual port; stacked connectors, many variations, saves board space and panel space! Male and female, male and male; 9-37 positions.

Filtered right angle types; standard .318, .370, .590 footprint; 9-37 positions; many mounting options.

Filtered high density D-subs; right angle types; 15, 26, 44 positions.

Filtered adaptors; 9-50 position for retrofit top panel, or in-line mounting to cables.

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- If you are already experience noise problems then our adaptors may save the day! You can easily retrofit your I/O connector or plug directly into your cable connector.
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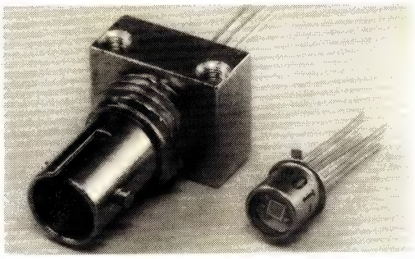
"FOR FREEDOM FROM EMI/RFI"

CIRCLE 167 FOR U.S. RESPONSE
CIRCLE 168 FOR RESPONSE OUTSIDE THE U.S.

FIBER-OPTIC DETECTOR HANDLES UP TO 50 MHZ

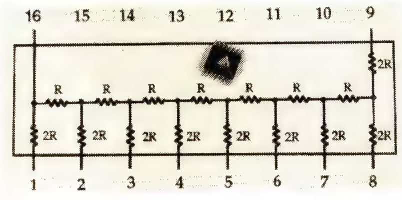
A low-cost fiber-optic detector for frequencies up to 50 MHz and distances up to 1 km is available for local-area networks at the 850-nm window. The BPX65-100 detector, which can be used with ST or SMA connectors, combines an ultra-high-speed silicon photodiode with a high-frequency op amp in a 6-pin TO-18 package. Pricing is $20 in single quantities with large-volume discounts available. Small quantities are delivered from stock. DM



Centronic Inc., 2088 Anchor Ct., Anchor Business Park, Newbury Park, CA 91320; Yuval Tamari, (805) 499-5902. **CIRCLE 628**

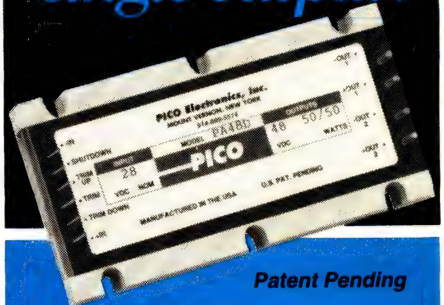
SMT LADDER NETWORK SAVES BOARD SPACE

An integrated R-2R ladder network (8- and 10-bit) is available in a space-saving 25-mil-pitch, 16-pin quarter-size-outline package. The PRN114 offers users a 50% reduction in board area when compared to conventional discrete R-2R implementations. Highly precise resistor networks are crucial to the performance of a-d and d-a data conversions, and the PRN114 network delivers precision with tightly matched component tolerances, temperature coefficients, and tracking characteristics. Pricing in lots of 10,000 is $1.50. DM



California Micro Devices Corp., 215 Topaz St., Milpitas, CA 95035-5430; Roy Selinger, (408) 263-3214. **CIRCLE 629**

Our Power Module is Dual... theirs is only single output!



Patent Pending

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CIRCLE 227 FOR U.S. RESPONSE
CIRCLE 228 FOR RESPONSE OUTSIDE THE U.S.

REFERENCE BOARD MIXES AUDIO, VIDEO, GRAPHICS

Rather than leave the integration up to the multimedia-system designer, a reference-board design integrates audio, video, and graphics processing on one AT-bus/VL-bus compatible card. The board, complete with Microsoft's Video for Windows software and customized MediaManager display drivers, including SuperMAc's CinePak decompression algorithm, are included with the card design. The "preintegration" of all the audio and video aspects proves that the various chips from Cirrus—the CS4231 audio processor, the CL-GD5428 VGA controller/accelerator with VL-bus interface, and the CL-PX2070 video processor—all work together.

Thanks to the high-speed VL-bus interface, the video-capture hardware included in the card design can capture 320- by 240-pixel images at rates of up to 30 frames/s, allowing the card to display quarter screen real-time video windows. The integration of all the multimedia functions onto one card could also reduce system clutter because one card could now typically replace as many as three cards—an audio card, a graphics card, and a video (JPEG or MPEG) card. The MediaManager demo kit sells for $2500 and a full manufacturing reference kit sells for $5000. DB

Cirrus Logic Inc., 3100 W. Warren Ave. Fremont, CA 94538. Eve Brasfield, (510) 623-8300.
CIRCLE 630

MODULE ADDS X-WINDOWS CAPABILITY

Real-time software developers can incorporate X-Windows into a family of processor boards using the Apex-200 graphics module. When combined with the OS-9 X-Windows software from Microware, the Apex-200 transforms a system into an X-Windows client and server workstation, while retaining *all* the capabilities of the OS-9 environment. The module employs a TI TMS34010 graphics processor, which maintains access to its own on-board local program and display memory. This architecture supplies a high-level interface by which graphics primitives can be downloaded for use by client applications. As a result, the overall overhead on the host CPU is reduced. The display resolution is fully programmable, up to 1024 by 1024 pixels. Prices for the Apex-200 start at $1445, including the X-Server run-time software. RN

Radstone Technology Corp., 20 Craig Rd., Montvale, NJ 07645; (800) 368-2738 or (201) 391-2700. **CIRCLE 631**

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- RS232 interface
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CIRCLE 155 FOR U.S. RESPONSE
CIRCLE 156 FOR RESPONSE OUTSIDE THE U.S.

SIP MODULES HOLD 600-V IGBTS AND 600-V FAST-RECOVERY DIODES

Designed to build high-power half bridges for six-step control of ac motors, the CPU165MF and 165MU skinny SIP (single in-line package) modules represent the smallest 600-V modules available, rated respectively at 43 and 35 Arms/phase in that application. Both contain two 600-V IGBTs and two 600-V fast-recovery epitaxial diodes (FREDs) for snubbing.

At a current of 23 A, the collector-emitter saturation voltage ($V_{ce(sat)}$) for the CPU165MF runs just 1.3 V. Its cohort, the CPU165MU, contains International Rectifier's proprietary "Ultra-fast" IGBTs. Its $V_{ce(sat)}$ runs 1.8 V at 17 A. Though somewhat less efficient than the CPU165MU, it can operate at a carrier-switching frequency of 20 kHz—the CPU165MU is limited to 5-kHz operation. Operation at 20 kHz eliminates the creation of audible noise in the motor or other magnetic components.

To simplify motor-control system design and increase efficiency, these half-bridge modules provide a built-in Kelvin connection to the emitter of both IGBTs. Each is brought out of the module to a pin adjacent to its respective IGBT's gate pin, providing a convenient point for the system designer to connect the gate-drive signal. The use of the adjacent pins lets designers minimize the length and area of the gate-drive connection, which in turn reduces stray inductance, making the device less susceptible to interference from stray electric fields.

The SIP measures 1.7 in. by 0.68 in. by 0.31 in. and provides 2500 V of isolation between the pins and its baseplate. In lots of 100, both devices cost $38.40 each.

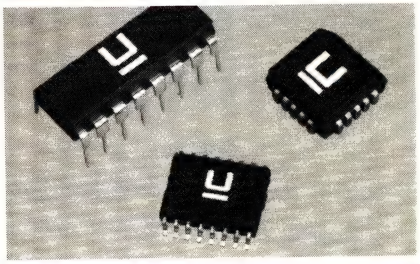
International Rectifier Corp., *233 Kansas St., El Segundo, CA 90245; Joe Ingoglia, (310) 607-8848.* **CIRCLE 632**

■ *FRANK GOODENOUGH*

1-MHZ SWITCH-MODE CONTROLLER USES SYNCHRONOUS RECTIFIER

The first PWM controller IC, the UC3824, offers the required complementary outputs for synchronous rectification and operates at PWM rates to 1 MHz. Synchronous rectification is particularly useful for output voltages below 5 V and, depending on the application, currents exceeding 10 to 100 A. Operating at switching frequencies close to 1 MHz results in smaller transformers, inductors, and capacitors. In all applications, the UC3824 can operate in either current-mode or voltage-mode topologies.

The controller also lends itself to transformer-isolated off-line and dc-dc forward-converters. In these applications, minimum EMI/RFI is often vital. However, the controller can also operate in a fixed-frequency, zero-voltage-switching (ZVS) topology, which reduces EMI/RFI and also further ups efficiency by lowering switching losses.

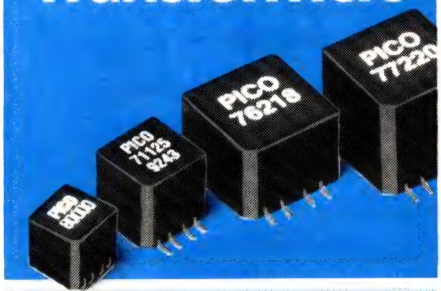


Protection circuits include a current-limit comparator, a shutdown input, undervoltage lockout, and a soft-start pin that doubles as a maximum duty-cycle clamp.

Package options for the UC3824 include 16-pin DIPs, wide-body 16-pin SOICs, and 20-pin PLCCs. In quantities of 1000, the commercial grade controller costs $4.20.

Unitrode Integrated Circuits Corp., *P.O. Box 339, Merrimack, NH 03054-0339; Ed Friedman, (603) 424-2410.* **CIRCLE 633**

■ *FRANK GOODENOUGH*



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- Low profile .2" ht.

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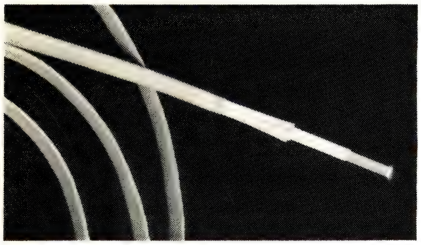

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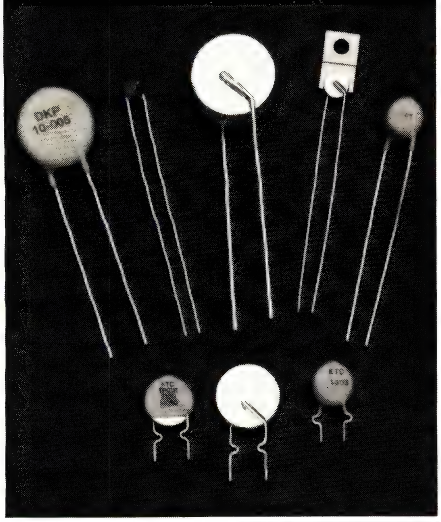

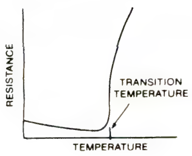

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SOFTWARE TOOL EASES DESIGN OF STATE MACHINES

Making it easier to design state machines, the software tool Better State makes it possible for state diagrams to include factors such as concurrency and hierarchy, while retaining the intuitive and visual appeal of state diagrams. Developed by R-Active Concepts, the program runs under the popular Microsoft Windows 3.x graphical user interface on IBM PCs and compatibles. With the software, users can create graphical images of state diagrams on one or more linked pages, annotate them, and then generate either VHDL, Verilog, or C-code to implement the state functions.

Such features make it much easier to create state descriptions for reactive control systems. Reactive systems have inputs (or outputs) that continuously and endlessly arrive (or are sent to) a plurality of partially correlated entities in the environment. For example, a telephone answering machine never has its inputs ready; inputs arrive continuously and endlessly, in a non-deterministic order (the order of the inputs is not known in advance).

In Better State, users can draw states, edges, illustrate threads of concurrent control, and annotate the diagrams. VHDL or Verilog can be used to annotate the diagrams, thus enabling the code in the diagram to refer to code written elsewhere. The windows also provide a visual page structure diagram that allows the user to comprehend and access all portions of the diagram with a mouse click. Smart graphics make it easy to manipulate the diagrams—when moving a state, all connected edges and text move with it. And to avoid a cluttered look, text can be hidden. Templates supplied with the software enable users to schedule the design deterministically, stochastically, or using specific scheduling algorithms (for example, round robin, and so forth).

A single-user version of Better State sells for $690. The software is available now.

***R-Active Concepts**, 20654 Gardenside Circle, Cupertino, CA 95014; Doron Drusinsky, (408) 252-2808.* **CIRCLE 637**

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TOOLKIT TARGETS PHILIPS μCONTROLLER

A low-cost software-development kit may help developers working with the Philips 87C750 microcontroller. The 87C750 SDK has a full-featured multiwindow text editor, a robust macro assembler, and simulator/source-level debugger. The DOS-based development package is configured to support an 87C750 target processor environment, including memory spaces and peripheral ports and timers. Also supported is a source debugging environment, including instruction single-stepping, breakpoints, watch windows, and 17 other tools. The kit goes for $39.95 until April 1994. SVT

Micro Computer Control, P. O. Box 275, 17 Model Ave., Hopewell, NJ 08525; (609) 466-1751; fax - 4116. **CIRCLE 638**

SOFTWARE ANALYSIS TOOL RECEIVES AN UPGRADE

Version 2.1 of the SmartSystem software analysis and comprehension tool adds a makefile reader to ease building a database and getting started. The upgrade supplies additional code comprehension capabilities that allow a user to work with a richer set of information in the call graph by showing dependencies involving global data and function pointers, besides function and library calls. Version 2.1 also supplies new mechanisms for uncovering undefined macros. The software analyzes many dialects of C, code with errors, and incomplete systems; it runs on Sparc, HP, and IBM platforms. Contact the company. SVT

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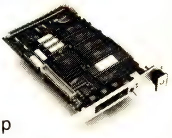

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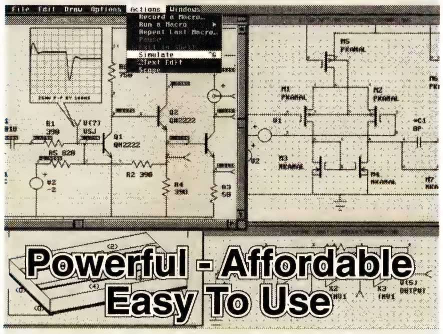

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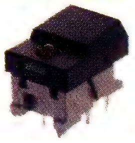

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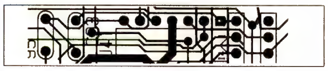

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BROADBAND POWER AMPLIFIERS

This guide from Amplifier Research, Souderton Pa., offers hints on selecting rf amplifiers in power range from 1 to 10,000 watts, frequency 10 khz to 1 GHz. Linearity, instant bandwidth, immunity to load mismatch are included in discussionn.

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AMPLIFIER RESEARCH

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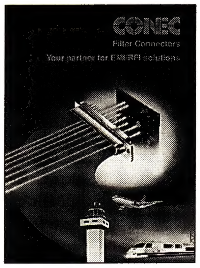

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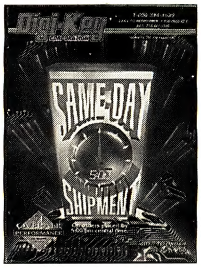

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TROUBLESHOOTING CIRCUITS

High-speed circuits are the focus of LeCroy's new Application Note. It discusses the uses of digital oscilloscopes to troubleshoot crosstalk, PC BUS Terminaions, grounding and other problems in circuits to 1 GHz.
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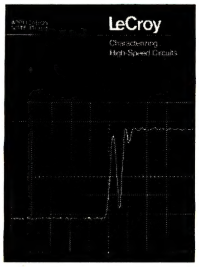

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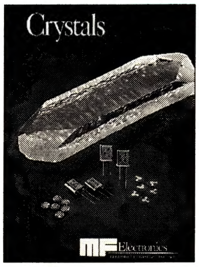
MF Electronics offers a new crystals brochure. Included is general crystal design information and quartz microprocessor and special crystal info. Detailed definitions and directions for selecting custom crystals are listed.



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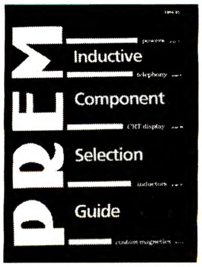
New catalog features entire line of power transformers, telecommunication magnetics, CRT products, and inductors. Power transformers carry UL and CSA listings. International series includes UL, IEC, VDE and CSA approvals. The telecommunications line includes coupling and hybrid transformers for voice and / or data, plus many other special applications.



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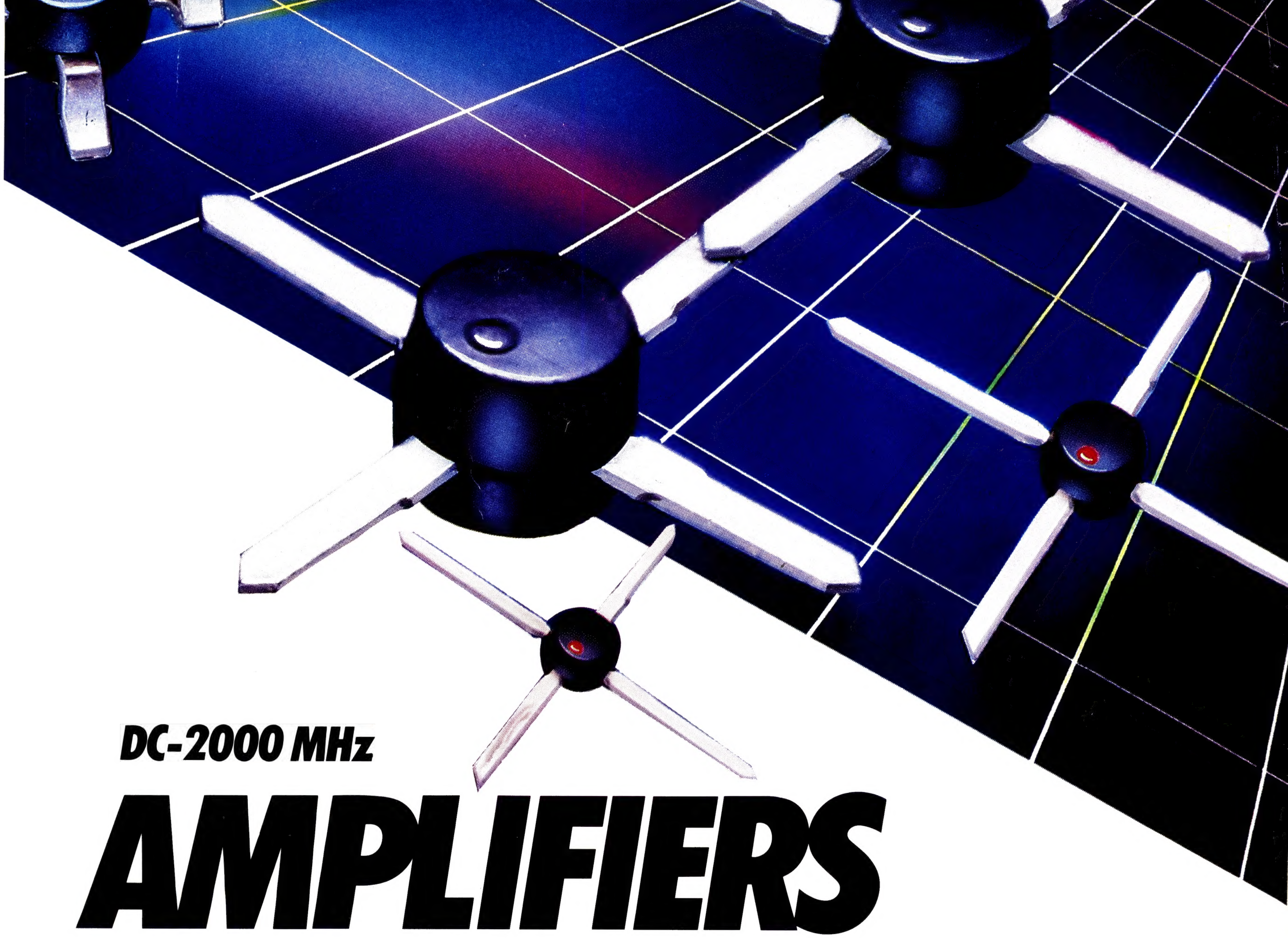
2500 AD SOFTWARE	400	149
AAVID ENGINEERING	80,81	121
ACCEL TECHNOLOGIES	187,188	62
ADVANCED MICRO DEVICES	139,140	54-55*
ADVANCED MICRO DEVICES	161,162	2-3
ALACRON	82,83	136
ALDEC	213,214	8
ALTERA CORPORATION	143,144	20-21
AMERICAN ARIUM	209,210	87
AMP INCORPORATED	159,160	40-41
ANALOG DEVICES	84,85	51
ANCOT CORPORATION	86,87	10
BURR-BROWN	207,208	36
BURR-BROWN	169-170	76
BURR-BROWN	---	73
BURR-BROWN	247,248	74
BURR-BROWN	249,250	75
CADSOFT COMPUTER INC.	165,166	122
CALOGIC	217,218	142
CIRCUIT COMPONENTS INC.	153,154	119
CIRRUS LOGIC	---	138-139
COMPONENTS CORP.	401	150
CONEC CORPORATION	167,168	144
CYBERNETIC MICRO SYSTEMS	163,164	14
CYPRESS SEMICONDUCTOR	---	82
DALLAS SEMICONDUCTOR	92,93	53
DALLAS SEMICONDUCTOR	215,216	10
DATA I/O	402	150
DATEL INC.	185,186	117*
DESIGN COMPUTATION	403	150
DIGI-KEY	94,95	22*
DIGITAL EQUIPMENT CORP.	225,226	COV2
DYNATEM	404	149
EAO SWITCH	405	149
ELANTEC	96,97	128
ELTEC	235,236	28**
HARRIS SEMICONDUCTOR	203,204	28*
HEWLETT-PACKARD	98,99	61
HEWLETT-PACKARD COMPONENT	221,222	1
HITACHI AMERICA	100,101	56*
HUGHES MICROELECTRONICS	239	79
HUGHES MICROELECTRONICS	102,103	22*
INTEL CORPORATION	145,146	32-33*
INTERACTIVE CIR. & SYS.	104,105	125
INTUSOFT	406	149
KEMET ELECTRONICS	211,212	133
KEYSTONE CARBON	199,200	148
KILOVAC	106,107	147
LAMBDA	108,109	80A-F
LINEAR TECHNOLOGY	231,232	COV4
MAXIM	191-192	89
MAXIM	193-194	91
MAXIM	195-196	93
MAXIM	197-198	95
MICRO NETWORKS	112,113	18
MICROSIM CORPORATION	305	35
MINI-CIRCUITS LABORATORY	114,115	24-25
MINI-CIRCUITS LABORATORY	116,117	15
MINI-CIRCUITS LABORATORY	118,119	COV3
MITSUBISHI ELECTRONICS	244,245	6-7
MOTOROLA COMPUTER GROUP	120,121	46
NATIONAL INSTRUMENTS	122,123	19
NATIONAL SEMICONDUCTOR	---	65
NCR MICROELECTRONICS	173,174	100
NEC ELECTRONICS INC.	124,125	42
NJR	183,184	126
NKK SWITCHES	---	114
NOHAU	181,182	109
PENTEK INC.	147,148	135
PHILIPS SEMICONDUCTOR	126	67,68,69
PHILIPS SEMICONDUCTORS	---	112*
PICO	227,228	144
PICO	227,228	146
PORTABLE BY DESIGN	---	49
PRECISION INTERCONNECT	205,206	104
PROTO EXPRESS	407	149
PULIZZI ENGINEERING INC.	189,190	84
RADSTONE TECHNOLOGY	175,176	131
SIEMENS	233,234	32-33**
SIEMENS COMPONENTS	177,178	111
SILICONIX INC.	---	11
SIMTEK CORPORATION	141,142	31
STANFORD RESEARCH	155,156	145
SUPERTEX INC.	127,128	106
TELEBYTE TECHNOLOGY	237,238	147
TEXAS INSTRUMENTS	219,220	16-17
TEXAS INSTRUMENTS	246	117
TEXAS INSTRUMENTS	171	49**
TICS REALTIME	179,180	143
TRANSISTOR DEVICES	229,230	70
TRIQUINT SEMICONDUCTOR	129,130	103
UNITRODE INTEGRATED CIR.	151,152	27
V3 CORPORATION	201,202	99*
VICOR	157,158	39
VIEWLOGIC SYSTEMS	131,132	59
VIEWPOINT INTERNATIONAL	408	149
VIGRA INC.	149,150	9
XILINX	135,136	12-13
YOKOGAWA	251	56**
Z-WORLD	409	149
ZILOG	137,138	45

DOMESTIC ONLY*
INTERNATIONAL ONLY**



DC-2000 MHz

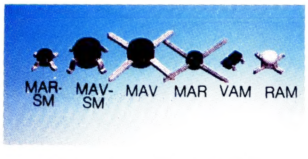
AMPLIFIERS

In plastic and ceramic packages, for low-cost solutions to dozens of application requirements, select Mini-Circuits' flatpack or surface-mount wideband monolithic amplifiers. For example, cascade three MAR-2 monolithic amplifiers and end up with a 25dB gain, 0.3 to 2000MHz amplifier for less than $4.50. Design values and circuit board layout available on request.

It's just as easy to create an amplifier that meets other specific needs, whether it be low noise, high gain, or medium power. Select from Mini-Circuits' wide assortment of models (see Chart), sketch a simple interconnect layout, and the design is done. Each model is characterized with S parameter data included in our 740-page RF/IF Designers' Handbook.

All Mini-Circuits' amplifiers feature tight unit-to-unit repeatability, high reliability, a one-year guarantee, tape and reel packaging, off-the-shelf availability, with prices starting at 99 cents.

Mini-Circuits' monolithic amplifiers...for innovative do-it-yourself problem solvers.



Models above shown actual size

from **99¢** Unit price $ (25 qty)

PLASTIC SURFACE-MOUNT			++VAM-3 1.45		+VAM-6 1.29	++VAM-7 1.75		
add suffix SM to model no. (ex. MAR-ISM)	MAR-1 1.04	MAR-2 1.40	MAR-3 1.50	MAR-4 1.60	MAR-6 1.34	MAR-7 1.80	MAR-8 1.75	
	MAV-1 1.15	+MAV-2 1.45	+MAV-3 1.55	MAV-4 1.65				MAV-11 2.15
CERAMIC SURFACE-MOUNT	RAM-1 4.95	RAM-2 4.95	RAM-3 4.95	RAM-4 4.95	RAM-6 4.95	RAM-7 4.95	RAM-8 4.95	
PLASTIC FLAT-PACK	MAV-1 1.10	+MAV-2 1.40	+MAV-3 1.50	+MAV-4 1.60				MAV-11 2.10
	MAR-1 0.99	MAR-2 1.35	MAR-3 1.45	MAR-4 1.55	MAR-6 1.29	MAR-7 1.75	MAR-8 1.70	
Freq.MHz,DC to	1000	2000	2000	1000	2000	2000	1000	1000
Gain, dB at 100MHz	18.5	12.5	12.5	8.3	20	13.5	32.5	12.7
Output Pwr. +dBm	1.5	4.5	10.0	12.5	2.0	5.5	12.5	17.5
NF, dB	5.5	6.5	6.0	6.5	3.0	5.0	3.3	3.6

Notes: + Frequency range DC-1500MHz ++ Gain 1/2 dB less than shown

designer's amplifier kits

DAK-2: 5 of each MAR-model (35 pcs), only $59.95

DAK-2SM: 5 of each MAR-SM model (35 pcs) only $61.95

DAK-3: 3 of each MAR, MAR-SM, MAV-11, MAV-11SM (48 pcs) $74.95

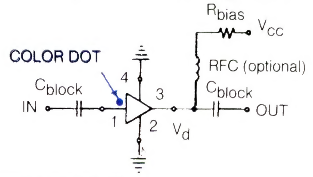
designer's chip capacitor kit

KCAP-1: 50 of 17 values, 10pf to 0.1μf (850 pc), $99.95

chip coupling capacitors at .12¢ each (50 min.)

Size (mils)	Value
80 x 50	10, 22, 47, 68, 100, 220, 470, 680 pf
80 x 50	1000, 2200, 4700, 6800, 10,000 pf
120 x 60	.022, .047, .068, .1μf

Typical Circuit Arrangement



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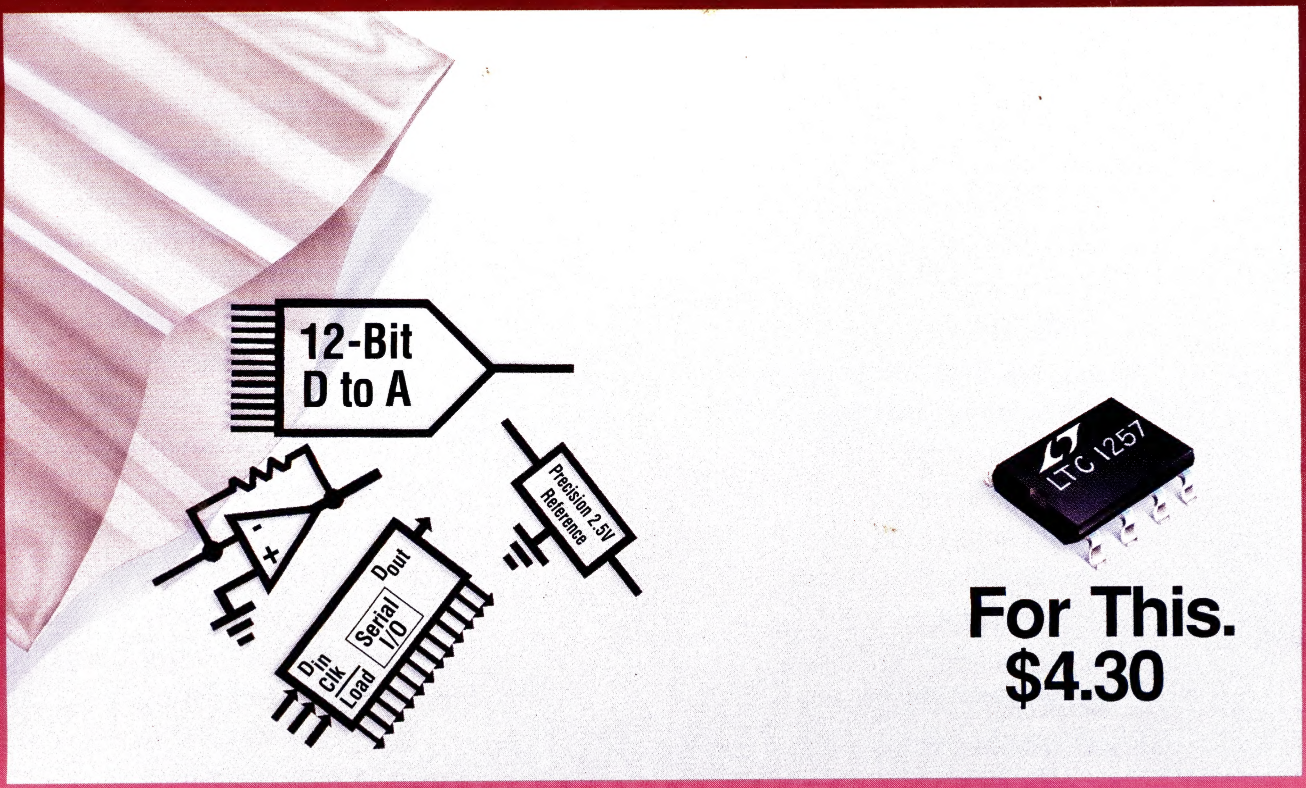
For detailed specs on all Mini-Circuits products refer to • THOMAS REGISTER Vol. 23 • MICROWAVES PRODUCT DIRECTORY • EEM • MINI-CIRCUITS' 740-pg HANDBOOK.

F154 REV. A

CIRCLE 118 FOR U.S. RESPONSE CIRCLE 119 FOR RESPONSE OUTSIDE THE U.S.

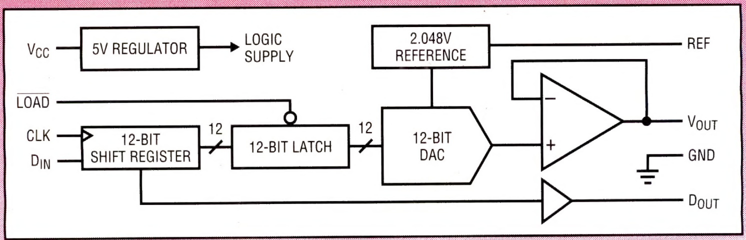
All This. In This.



For This.
$4.30

The LTC1257. Complete 12-Bit Serial SO-8 DAC.

Using a 12-bit DAC is now easier than ever! The new LTC1257 is a complete 12-bit DAC in a very small 8-pin SO package. No external components are needed. And the price may be the easiest thing of all! Included is an output buffer amplifier, a 2.048V voltage reference and an easy to use cascadable three-wire serial interface.



The power supply current is a very low 350µA typ. when using a 5V supply. Excellent differential non-linearity—less than 1/2 LSB—guarantees monotonicity and makes the LTC1257 ideal for control and adjustment applications. And you get flexibility—the single supply voltage can go from 4.75 to 15.75 volts and you can override the internal reference to extend the output range as high as 0-12 volts.

The DAC's small size and low power consumption make it ideal for battery powered systems. And with the cascadable serial interface, applications using multiple DACs are a breeze. So if you want to reduce your system cost and complexity, the LTC1257 is a natural choice. Parts are available in 8-pin SO packages or 8-pin DIP. Pricing in 1000-up quantities starts at $4.30. For more details, contact Linear Technology Corporation, 1630 McCarthy Blvd., Milpitas, CA 95035/408-432-1900. For literature only, call **1-800-4-LINEAR.**

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